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PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that members send information regarding their movements to the Secretary, for insertion under this heading.

Mr. A. J. BROWN has returned to Penang, Straits Settlements.

Mr. G. N. CRITCHLEY is home from Trinidad.

Mr. W. L. FORSTER has left Holland and is in Rumania.

Mr. M. E. KELLY is in Persia.

Mr. W. L. MADDEN is home from Mexico.

Mr. R. H. MITCHELL is returning home from Palestine.

Mr. R. NISBET has left Assam and is in Scotland.

Mr. A. E. PAGE has left for the Gold Coast Colony.

Mr. J. S. PARKER is home from Egypt.

Mr. AGUSTIN ROSAS has been confirmed by the Argentine Chamber of Senates as a Director of the Yacimentos Petroliferos Fiscales.

Mr. J. STUART SMITH has left for Ecuador.

Mr. D. A. SUTHERLAND is in Palestine.

The Secretary would be glad to learn of the whereabouts of the following members: E. E. G. AGIUS, A. E. C. CORBET, E. J. S. HEWITT, A. MACLEAN, D. J. PULL, P. A. STIFF and R. W. STILES.

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No. 118, Vol. 19.

Some Methods in Oilfield Water Analysis.*

By W. A. Macfadyen, M.C., Ph.D., F.G.S. (Member).

In the years 1922 to 1925 the writer was occupied as exploitation geologist on the oilfield of Hurghada, Egypt, and found it necessary to study the various oilfield waters in some detail. There was no chemist resident at Hurghada, and water samples had to be sent by boat to Suez or Cairo for analysis, which meant a delay of commonly up to seven days after collecting the sample before the analysis results were received by telegraph. The writer found that to hold up a drilling well for a week whilst awaiting a water analysis which might or might not give the definite information required, did not make for the satisfaction of the management or anyone else on the field, and so he was driven to attempt his own estimations. After considerable experiment methods of adequate accuracy were worked out which gave the data for the solution of any water problem at Hurghada capable of solution by the analyses as usually given by the chemists. Volumetric methods were used, and it was found that when in practice, with reagents made up, the requisite estimations of chloride, sulphate, lime, ferrous iron and hydrogen-ion concentration, with a qualitative test for alkaline polysulphides, could be made under pressure in so little as one and a half hours' work. These estimations included three not usually made by the chemists—iron, p_H and polysulphides—and omitted magnesia, which the writer failed to find of any value. It was found convenient to have a sample of not less than half a litre of water, though in case of need half this quantity would, with care, suffice.

The errors inherent in the methods used were not studied; it sufficed to know that, *when carefully carried out*, the results checked sufficiently well with the estimations made by competent chemists on the same water sample. It may be pointed out, also, that for the solution of most oilfield problems of a routine description (*i.e.*, at Hurghada), great accuracy is unnecessary and approximate figures are adequate, so long as they are consistently reliable and within the limits of permissible error found by experience in the case of each ion. Incidentally it may be noted, as was remarked, at the time by Mr. R. D. Vernon, that sea-water is sufficiently constant in composition to afford a useful standard, in the absence of better means, against which to check one's estimations.

It is thought that a note on the methods adopted may possibly be of use to other geologists thrown on their own resources in similar

* Paper received January 25, 1933.

cases, with very little in the way of laboratory equipment, so that it is hoped the chemists will condone this encroachment into their field.

Chloride Estimation.—The usual method of titration with decinormal silver nitrate, using potassium chromate as indicator, is used. The only novelty lies in the method adopted in taking a very small sample for titration, obviating the otherwise necessary high dilution of the brine with distilled water before taking the usual 10 to 25 ml. to titrate.

A certain marked pipette (or better, burette) which will always be used for this operation in the future, is taken, carefully rinsed with a filtered sample of the brine and partially filled with it. Four drops (or a similar convenient number) are then very carefully and *very slowly** released into a white porcelain evaporating dish containing 15 to 20 ml. of distilled water, and titrated with decinormal silver nitrate in the usual way.

The method is standardized by titrating four drops of several waters whose chloride contents are accurately known. On account of surface tension effects brines of widely differing salt content give slightly differently sized drops, but it was found that two brines, one dilute and the other concentrated, were adequate for practical standardization, the factor being worked out separately for each and the more appropriate one used in future estimations.

The following experimental results were obtained: four drops from a certain pipette of two brines containing 31 and 130 gm. Cl./litre respectively were titrated. From these results 1 ml. of decinormal silver nitrate was found to be equivalent to 17·3 and 18·2 gm. Cl./litre in the two brines.

Hence, if four drops of a new water required 6·3 ml. decinormal silver nitrate, its chloride content would be about $6{\cdot}3 \times 18{\cdot}2 = 114{\cdot}7$ or, say, 115 gm. Cl./litre. The following table shows the results obtained in the first (consecutive) series of estimations made by this method:—

Four drops titration. gm. Cl./litre.	Egyptian Government Chemical Dept. gm. Cl./litre.
58	58·8
91	88·0
113	117·2
134	136·4
49	49·2
84	83·2
93	91·6
28	28·8

* Each drop should be allowed not less than about five seconds to develop and fall, otherwise it will be of smaller than the maximum size.

Two or three titrations were, of course, invariably made for every sample to obviate accidental errors. Temperature corrections seem to be unnecessary when the estimations are carried out at laboratory temperatures.

Sulphate Estimation.—Since no simple volumetric method seems to be known, the method of trial and error, applied volumetrically, was adopted. A rough preliminary observation was made, however, and after a little practice this, carried out in a few seconds, was found to save much time in the final estimation.

About 5 ml. of rectified alcohol* is taken in a test tube, and 5 to 10 drops of the filtered water sample added from a pipette, with shaking. From the turbidity produced a rough estimate of the sulphate content of the water may be made, as follows :—

Very low sulphates : 0·5 gm. SO_3/litre or less ; slight turbidity.

Low sulphates : 0·5 to 1·5 (very roughly) ; considerable to great turbidity.

High sulphates : 1·5 to 5·0 (very roughly) ; apparently less turbidity than lower sulphates give, but with a definite flocculent precipitate.

Very high sulphates : 5·0 or more (very roughly) ; as the last, but with more abundant flocculent precipitate.

For the definite estimation a measured quantity of standard acidified barium chloride solution is run from a burette into 10 ml. of the brine in a test tube. (This first amount depends on the judgment of the observer as a result of the preliminary test, or of his knowledge of the probable sulphate content of the sample under examination.) The mixture in the test tube is shaken for a moment, boiled, and filtered ; repeatedly through the same filter-paper where necessary, until the filtrate is crystal clear. A portion of this clear filtrate is then tested for presence or absence of sulphate (all of which may or may not have been precipitated by the amount of barium chloride added) by the addition of a little more (0·5 to 1·0 ml.) of the barium chloride, as a qualitative test. If a precipitate forms it is obvious that less than an equivalence of the standard barium chloride has been added in the first operation. If no precipitate forms, a little rectified alcohol (*not* absolute alcohol, see note above) is carefully poured down the side of the test tube to float on the liquid. Any traces of sulphate unprecipitated by the first barium chloride addition will then be visible as a white cloud at the junction of the two liquids. If only the slightest trace is left a hazy bluish ring will be seen, visible only by reflected light. If no cloud or ring forms, even on slight mixing of the

* Absolute alcohol should not be used since it often gives an initial heavy precipitate of salts other than sulphates.

two layers of liquid, the whole of the sulphate has been precipitated by the first barium chloride addition.

A second test tube with another 10 ml. of the brine is then taken and the same operations repeated, using initially more barium chloride from the burette if the sulphate had not all been precipitated in the first experiment or less if the converse was the case. These little experiments are continued until the sulphate value is confined by trial to within sufficiently narrow limits. In practice it was found advantageous to make additions of the barium chloride in *even numbers* of ml. or tenths. Thus the quantities added in the estimation might be successively 4, 2, 2·8, 2·4, 2·6 ml., the true equivalent being found to lie between, let us say, 2·4 and 2·6 ml., that is, with the standard barium chloride solution used, between 1·2 and 1·3 gm. SO_3/litre.

For a water of unknown sulphate content, after a little practice, a result to within 0·1 gm. SO_3/litre may be obtained by five or six little experiments within half-an-hour. It may be noted that at first much of the barium sulphate precipitate may pass the filter paper. In this case it is much quicker to use the same filter paper for the whole of the experiments, rinsing it out carefully with distilled water two or three times, and leaving a little to filter through it between each experiment. If this is done the first ml. of the next filtrate is rejected, but the liquid will come through practically or quite clear the first time through the filter.

For this quantitative precipitation N/8 barium chloride, acidified with about 2·5 per cent. hydrochloric acid was found convenient, made up by dissolving 15·275 gm. of purest barium chloride crystals ($BaCl_2 \cdot 2H_2O$) in distilled water, adding 25 ml. of pure concentrated hydrochloric acid, and making the whole up to 1 litre with distilled water. A 10 ml. sample of brine containing x gm. SO_3/litre will require $2x$ ml. of this standard barium chloride solution for the exact precipitation of its sulphates. In the Hurghada waters the sulphate content varied from 0·1 up to nearly 20·0 gm. SO_3/litre.

The following table shows the results obtained in a consecutive series of actual estimations, compared with the Egyptian

Trial and Error method. gm. SO_3/litre.	Egyptian Government Chemical Dept. gm. SO_3/litre.
2·2	2·2
2·9	3·0
13·5	14·2
0·3	0·1
0·3	0·2
2·3	2·3
0·55	0·5
0·95	1·1

Government Chemical Department's values from a part of the same water sample, and gives an idea of the accuracy of the method.

Lime Estimation.—The method adopted was the well-known one of converting the lime into calcium oxalate, acidifying, and then titrating the liberated oxalic acid by means of standard permanganate. Perhaps details as applied to the case in question may be of use.

A 10 ml. sample of the filtered brine is taken, and roughly 10 to 20 ml. of about 10 per cent. ammonium chloride solution, and a similar quantity of dilute ammonia added to it in a beaker, and the whole heated. If a precipitate of iron hydroxide forms at this stage it should be filtered off, the filter thoroughly washed with distilled water and the washings added to the filtrate so long as they contain any trace of lime. This is proved by the formation of a precipitate on the addition of a few drops of a mixture of ammonia, ammonium chloride, and oxalic acid to a sample of the warmed washings in a test tube. If it forms, the contents of this test tube are added to the clear filtrate. The filtrate is again heated and an excess of approximately normal oxalic acid (63 gm. of the crystals made up to 1 litre) added, and the mixture boiled for a few seconds. It may be noted that 15 ml. of *N* oxalic acid, equivalent to a lime content of the water sample of 44 gm./litre, is amply sufficient for all Egyptian oilfield waters. So long as an excess is present, however, the less surplus oxalic acid is added the better. After standing for a minute or two for the precipitate to settle, the clear liquid is decanted off through a filter. The precipitate remaining in the beaker is washed repeatedly with distilled water and ammonia chloride and ammonia, at first by decantation, until the filtrate gives no precipitate when tested by adding a few drops of calcium chloride solution and heating for a moment in a test tube.

Up to this point the mixture should smell strongly of ammonia, and it is usually necessary to add more ammonia after the addition of the oxalic acid. The filter-paper with the traces (or more) of calcium oxalate is now transferred to the main precipitate in the beaker, and about 20 ml. of an approximately 10 per cent. solution of pure sulphuric acid added, and the whole warmed, when all the calcium oxalate will pass into solution. If a needle-like precipitate of calcium sulphate is formed at this stage or later it may be ignored. The whole is then filtered, the old and new filter papers being repeatedly rinsed with acidulated distilled water; these washings are added to the filtrate, which is made up thus to exactly 100 ml. when cooled. This filtrate now contains as free oxalic acid the chemical equivalent of the calcium in the original 10 ml. brine sample.

Of this 100 ml., 10 ml. is taken in a dish, a little dilute sulphuric acid added, and the vessel warmed; it is then titrated with decinormal potassium permanganate in the usual manner. 1 ml. of the permanganate is equivalent to 2·8 gm. CaO/litre of the original brine.

The estimation may give a slightly low value for the lime, owing to loss due to imperfect washing of the several filter papers, and a small correction usually equivalent to between 0·05 and 0·1 ml. of permanganate may be added in compensation. This estimation takes some time to carry out, chiefly owing to delay for the thorough washing of the filter papers. It appears to give results correct to well within 1 gm. CaO/litre for brines containing between 1 and 35 gm. CaO/litre. For waters with very low lime (1 to 5 gm./litre) a 20 or 50 ml. sample should be taken for the estimation, instead of the usual 10 ml., and the final result of the titration divided by 2 or 5 respectively.

Ferrous Iron Estimation.—At Hurghada ferrous iron was definitely a normal component of the lower waters, and was not due to solution of casing or other adventitious origin. In value it varied between about 0·02 and 0·5 gm./litre—*i.e.*, 20 to 500 parts per million. A qualitative test for its presence, using potassium ferrocyanide as indicator, was useful, since this simple colour test immediately differentiated a lower from an upper water. Estimations of the ferrous iron were of value in assisting to differentiate between several lower waters.

On account of the rapid precipitation of hydroxide of iron on standing a filtered water sample should be acidified with a few drops of pure concentrated hydrochloric acid as soon as possible after taking the main sample from the well. This prevents precipitation of the iron, but the sample should be titrated as soon as conveniently possible, otherwise a low result may be obtained owing to partial oxidation to the ferric state.

In Hurghada waters the iron is entirely in the ferrous state, and it may be estimated by titration with standard potassium dichromate using potassium ferricyanide as external indicator in the usual way. Standard permanganate cannot be used owing to the high chloride content of the brines, which interferes with the titration. Owing to the low value of the iron content of the waters a sample of 50 or 100 ml. should be taken for titration, and dilute dichromate used, the titration being kept well acid by the addition of a little dilute hydrochloric acid, otherwise a sharp end-point is not obtained. A convenient standard solution is made by taking 139·2 ml. of decinormal dichromate and making it up to 1 litre with distilled water. Titrating a sample of 100 ml.

of brine with this, 1 ml. of dichromate is equivalent to a content of 0·01 gm. FeO/litre.

Using a *freshly made up* solution of potassium ferricyanide as indicator an estimation to 0·001 gm. FeO/litre can easily be obtained. In case of inconsistent results the first thing to be suspected is the indicator, which should be thrown away and a few ml. of a fresh solution made ; it is desirable, in fact, to use freshly made up indicator each day. If trouble is experienced owing to the formation of a dark blue colouration and slight precipitate when the dichromate is run into the acidified water sample, the latter should be warmed slightly previously to commencing the titration.

Hydrogen-ion Concentration.—At Hurghada a simple colorimetric estimation of this was found useful, since almost all the upper waters, including fresh drilling water and sea-water, have a p_H of about 8, and give a green colouration with the indicator used, whereas the lower waters of the oil zone all give slightly acid values, p_H 6 to 3, or orange-yellow to bright red with the same indicator. The acid waters are thus correlated with a content of ferrous iron. Certain upper waters containing high polysulphides gave a p_H of about 11, indicated by a violet colouration, and the same was found of all waters strongly influenced by recent cementing operations.

The "Universal Indicator," prepared by Messrs. British Drug Houses, Ltd., was used ; it is said to indicate values of p_H from 3 to 11 by a series of colours, a table supplied by the manufacturers serving to correlate colour with p_H. It was used by the writer by adding two or three drops of the indicator to a little more of the water sample in a white evaporating dish and observing the colour produced. The accuracy of this method, carried out perhaps more crudely than the makers of the indicator intended, was not checked. It sufficed that the results were easily and quickly obtained, and proved of considerable value to the writer.

Qualitative Test for Alkaline Polysulphides.—Certain waters associated with the shallow oil zones, or even below these, at Hurghada are of a light to dark primrose colour, and smell strongly of sulphuretted hydrogen. They contain alkaline polysulphides, and for their recognition, sight and smell are adequate indicators. Other waters, however, occasionally contain traces of polysulphides, which may be conveniently detected by adding a few drops of a solution of sodium nitroprusside. This reagent gives an evanescent violet colouration, which is said not to be produced if sulphuretted hydrogen alone is present.

A solution of sodium nitroprusside may be simply prepared by boiling a little solid potassium ferrocyanide with concentrated

nitric acid and neutralising the resulting solution with sodium carbonate.

For permission to publish these notes the writer is indebted to the kindness of the Anglo-Egyptian Oilfields, Limited, in whose service the processes were devised; and also to the Controller of the Department of Mines and Quarries of the Egyptian Government for permission to quote certain figures for comparison, which were taken from the analyses made by the Egyptian Government Chemical Department and supplied to the Company through the Department of Mines.

Principles of Gaslift.*

By Jan Versluys.

In oilfield parlance it is customary to restrict the term gaslift to the process of flowing a well by means of, or with the aid of, artificially injected gas. However, as the flow is essentially the same, irrespective of whether the well is producing with only formation gas, or with injected gas, the expression "gaslift" will hereinafter be used to cover both natural and induced flow.

According to the first principle of hydrostatics, if a pipe is connected to an open top tank, the liquid contained in this tank can rise in the pipe only to the level of the liquid in the tank, and this applies equally well to a pipe placed inside the tank. This, of course, only holds true when the air pressure above the liquid in the pipe is the same as that above the liquid in the tank.

The principle of the gaslift is that by introducing a gas into the liquid, which can rise together with the liquid in a pipe placed as referred to above, the liquid can be raised to a level above that of the liquid in the tank. This is shown diagrammatically in Fig. 1, where, in order to simplify matters, an open tank has

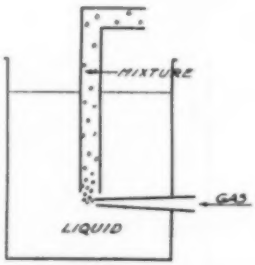


Fig. 1.

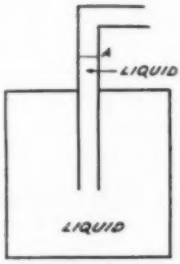


Fig. 2.

been considered, although a closed one may also be used. In the latter case the liquid can be considered as contained in the tank under a pressure which would raise it in a pipe to the level A. (See Fig. 2.) When liquid is continuously supplied at a constant pressure, then it is possible (see Fig. 3) to make the liquid flow out at B by introducing gas at the pressure of the liquid.

The above corresponds to what takes place in wells. The liquid comes from a layer in the well at a pressure which is much too

* Paper received January 30, 1933.

low to force a column of the liquid to the top of the well. However, if gas is produced with the liquid from the layer, at the same pressure, or is introduced (as in the case of gaslift in the practical sense of the term), it can cause the liquid to flow from the well.

FIG. 3.

To describe the manner in which gas assists in raising the liquid to above the hydrostatic level, a start can be made again from liquid in an open tank, in which an open pipe is immersed vertically to a certain depth. (See Fig. 4.)

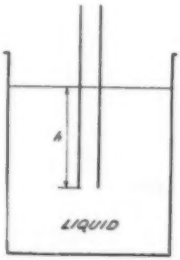


FIG. 4.

The atmosphere exerts a pressure on the liquid level. This pressure is assumed to be a units of force per unit of surface.

When the pipe is immersed h units of length, the pressure at the lower end of the pipe in the tank will be

$$a + h\gamma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where γ is the specific gravity of the liquid. The atmosphere also exerts a pressure a on the liquid level inside the pipe, so that the pressure at the bottom of the pipe will be

$$a + h_1\gamma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

when the pipe is filled with liquid to a height h_1 from the lower end. This pressure has to be in equilibrium with that outside the pipe, so that

$$a + h_1\gamma = a + h\gamma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

or

$$h_1 = h \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

so that the liquid levels are the same inside and outside the pipe. This well-known principle is only mentioned as an introduction to the arguments that follow.

Assuming a case when the liquid column in the pipe is broken by a cylinder of constant shape, lying like a piston against the wall and preventing liquid from passing, then an equation of equilibrium can again be obtained. (See Fig. 5.) It will be assumed that the weight of the cylinder (hereinafter referred to as the "piston") is so small that it may be neglected.

Assuming that the height of the liquid in the pipe above the

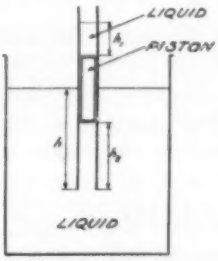


FIG. 5.

piston is h_1, and below is h_2, then the pressure on the top of the piston in units of force per unit of surface will be:

$$a + h_1\gamma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

and assuming that there is no friction, the piston will transmit the same pressure to the liquid below. At the bottom of the pipe the liquid in the pipe consequently exerts a pressure:

$$a + h_1\gamma + h_2\gamma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

which has to be in equilibrium with the pressure in the tank at the bottom of the pipe, so that

$$a + h_1\gamma + h_2\gamma = a + h\gamma \quad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

and consequently:

$$h_1 + h_2 = h \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

A piston having no weight and without friction in the pipe will,

therefore, raise the liquid level over a distance corresponding to its own height.

The same applies when a number of pistons are present. When, instead of liquid only, the pipe contains a column consisting of alternate small columns of liquid each with a height l_1, and pistons each with a height l_p; then, since the pistons are assumed to have no weight, the total length of the columns of liquid must be equal to h and one may write $ml_1=h$, where m is the number of pistons in the pipe and h is the original liquid column when no pistons are present; or, in other words:

$$m = \frac{h}{l_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

and the total height of the column:

$$m\,(l_1 + l_p) = \frac{h}{l_1}(l_1 + l_p) = h + h\frac{l_p}{l_1} \quad \ldots\ldots\ldots \quad (10)$$

The column in the pipe consequently reaches a height of $h\,\frac{l_p}{l_1}$ above the liquid level in the tank. The height to which the column in the pipe rises above the liquid level in the tank is therefore:

Proportional to the depth of immersion h;

Proportional to the total length of all the pistons;

Inversely proportional to the height of the liquid between two pistons.

It can, however, also be said that $\frac{l_p}{l_1}$ is the ratio between the total volume of the pistons and that of the liquid in the pipe. When this ratio is called n, the height to which the column in the pipe rises above the liquid level in the tank is

$$H = hn \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

i.e., the product of the depth of immersion and the ratio of the total volumes of pistons and liquid in the pipe. It should be repeated that the weight of the pistons is considered to be negligibly small and that there is no friction.

When the length of each piston and also that of each column of liquid between two pistons is small, one might speak of a mixture of liquid and pistons (see Fig. 6) filling the pipe to a height H above the original liquid level.

Suppose the pipe is cut off at a height H_1 above the liquid level so that

$$H_1 < H \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

The column cannot be in equilibrium with the existing pressure of the liquid in the tank, and therefore will rise. Consequently

liquid mixed with pistons will flow over. When new pistons are continuously added, and spaced at the same distances apart at the lower end of the pipe, then a regular lift of liquid results.

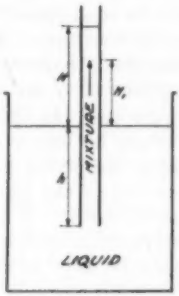


FIG. 6.

Energy is continuously consumed to raise liquid from a depth h, where the existing pressure is $a+h\gamma$, to a height $h+H$. On the other hand, energy is supplied by the transposition of liquid and pistons from the lower end of the pipe, where a pressure $a+h\gamma$ prevails, to a point (at the top of the pipe) where the pressure is a.

Energy has, however, always to be supplied to carry the pistons, having a certain volume but no weight, from a space at atmospheric pressure a into the liquid to a depth where the pressure is $a+h\gamma$.

Although it has been taken that there is no friction, it must not be concluded that the column rises with infinitely great speed, because energy is consumed for accelerating the liquid in the pipe.

A certain amount of friction may, however, occur and slow down the movement, but it will not cause a cessation of flow.

A similar nature of flow as above may be imagined, but in which the pistons do not fit tightly, so that liquid can descend between the pistons and the wall of the pipe. When the *free cross sectional area* around all pistons is assumed to be equally large, and since the pressure difference between the top and bottom of each piston is the same, then equal quantities of liquid will descend per unit of time along all pistons. Thus, if the statical condition is first established in which the pipe up to a height H above the liquid level in the tank is filled alternately with liquid columns and pistons, then the liquid columns will disappear successively—*i.e.*, first the top one, then the second and so on. However, as the liquid sinks away from the top, the column must rise. When pistons are continuously added at the bottom, then a column of

alternating liquid columns and pistons will rise, but the liquid in the pipe will always be maintained at the same level. It is true that more and more pistons accumulate at the upper end, but these are assumed to have no weight. The condition as depicted by Fig. 6 can therefore only be maintained by continuously adding pistons at the lower end of the pipe. As already stated above, power is required to do this (viz., the energy necessary to submerge light objects from the surface to a certain depth into a liquid).

The slipping of the liquid past the sides of the pistons can be called "slippage," the effect of which can only be neutralised by continuously applying or supplying power. Each piston at a depth h (*i.e.*, at the lower end of the pipe) below the liquid level represents a certain amount of power. When leakage or "slippage" takes place, and the pistons encounter a certain resistance when rising, the column can only be kept at constant height by introducing more pistons.

In a case when slippage occurs, liquid can also flow over when the pipe is cut off below the level of maximum height of the column. However, in order to lift the same quantity of liquid per unit of time a greater number of pistons must then be introduced.

The same applies when, instead of pistons, small globules are added at the lower end of the pipe. In this case the loss owing to slippage is increased, but there is no actual difference in the nature of the flow.

So far, reference has been made to pistons and globules, the volumes of which are considered to be constant. Assuming now pistons that expand as the pressure decreases, but which do not permit any liquid to bypass, the column will rise higher with expanding pistons than with pistons whose lengths remain the same as at the bottom of the pipe, as these expanding pistons reach a higher level in the pipe, the pressure to which they are exposed decreases, and the pistons expand so that the column becomes higher and the liquid will be raised higher with the same number of pistons per unit of volume of liquid. Thus the pistons do work when expanding. The same applies when the pistons allow liquid to pass, and also when the above-mentioned globules of constant volume are changed for gas bubbles which expand as the pressure decreases. In this manner it can be explained how the gas exerts energy by expansion in a gaslift system, because a body which can expand with decreasing pressure represents at a certain depth below the liquid level more energy than an equally large body at the same depth which cannot expand. This can be explained as follows :—

The upward force which the liquid exerts on a body of constant volume is constant, but the force exerted on a body of variable

volume increases as the body expands—*i.e.*, when it rises. If these two bodies, one of which does not expand whilst the other expands with decreasing pressure, are present at the same depth under water and both are allowed to rise, then the force exerted on the former will not increase, but the force exerted on the latter will increase as they reach a higher level, so that the force acting on the latter exerts more energy over the same distance. Inversely, more energy is consumed in submerging the compressible body to the required depth than the body of constant volume, when both bodies have the same volume at the lowest point. Consequently nothing is gained, because the available amount of power has first to be supplied.

The above references to pistons having no weight, of constant volume, and without leakage, which are able to raise the liquid above the level in the tank, apply equally well to pistons which allow liquid to pass, and also to globules rising freely. In the two last cases there is, however, a certain loss of energy.

The pistons or globules perform work by raising liquid to above the level in the tank. They represent energy because they move from the lower end of the pipe, where there is a certain liquid pressure in addition to the atmospheric pressure, to the overflow level, where there is only the atmospheric pressure. If the pistons or globules take the form of gas bubbles, they exert further work by expansion. It has already been explained how this has to be interpreted, and why this capacity to expand represents energy.

In the foregoing, reference has been made to a pipe containing columns of liquid, alternating with closely fitting pistons of constant shape. These pistons were then imagined to be leaking and then replaced by firm globules, and finally by gas bubbles. The gas then performs work owing to its volume moving from a place of high pressure to a place of low pressure, whilst, moreover, the volume becomes larger by the expansion.

The question of the rising of gas and liquid through a pipe will be discussed in more detail in a separate paper.

Conditions under which Gas and Liquid Mixtures Rise.*

By Jan Versluys.

In a previous paper it has been explained that it is possible to raise a liquid in a pipe above the original level in the reservoir by the aid of compressed gas.

This paper gives a discussion of the principles limiting the different conditions under which the flow of gas and liquid through a vertical pipe can take place. The principles are exposed as simply as possible, and all unessential complications have been omitted.

When a mixture of liquid and gas is rising in a tube, two stable conditions are possible, viz., the foam and the mist condition.

The *foam* condition arises when more liquid is present than gas. The gas is then distributed in the liquid in the form of bubbles, so that a cross-section through the flow tube would be represented diagrammatically as shown in Fig. 1 (the liquid is shown in black, the blanks representing gas bubbles.) That is to say, the flow resembles a rising column of froth.

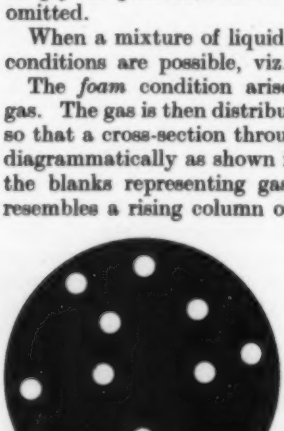


Fig. 1.

FOAM CONDITION.—BUBBLES OF GAS IN A CONTINUOUS MASS OF LIQUID. MORE LIQUID THAN GAS, DIFFERENTIAL VELOCITY, 1 FOOT PER SECOND.

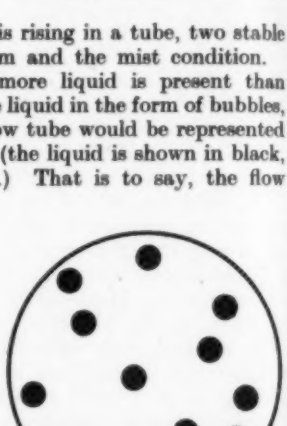


Fig. 2.

MIST CONDITION.—DROPS OF LIQUID IN A CONTINUOUS MASS OF GAS. MORE GAS THAN LIQUID, DIFFERENTIAL VELOCITY, 30 FEET PER SECOND.

In a liquid which is at rest, gas bubbles tend to rise with a small velocity, the value of which depends mainly on the size of the bubbles and on the properties of the gas and the liquid, but which may be taken as approximately 1 ft./sec. When the liquid rises, this relative velocity is not materially altered, so that the upward velocity of the gas exceeds that of the liquid by 1 ft. per second.

* Paper received January 30th, 1933.

The *mist* condition prevails when the volume of the gas in the mixture is bigger than that occupied by the liquid. In that case the liquid is distributed in the gas in the form of drops, and the flow resembles a spray. A cross-section of the tube, showing the mist condition, is represented by Fig. 2.

When the gas is at rest, drops of liquid tend to fall in a gas-filled space, and it has been experimentally determined by various investigators that the final velocity of the drops is then about 30 ft. per second. Therefore, the gas has to rise with a velocity of more than 30 ft. per second, before drops of liquid will be carried up by it.

In other words, when the mist condition prevails, the upward velocity of the drops of liquid is 30 ft. per second lower than the upward velocity of the gas.

Summarizing, it may be repeated that two stable conditions are possible, when liquid and gas are rising through a tube :—

A. The foam condition with the following characteristics :
   First, more liquid than gas in the mixture ;
   Second, small difference in the velocities of the gas and liquid.
B. The mist condition with the characteristics :
   First, more gas than liquid in the mixture ;
   Second, great difference in the velocities of the gas and liquid.

For the sake of simplicity, it will at present be assumed that 50 per cent. liquid and 50 per cent. gas in the mixture is the limit between foam and mist. This subject will be considered more fully later on in the paper.

Suppose a tube is divided into two channels by means of two partition walls, placed radially. Let the case where there is no difference in velocity between the gas and the liquid be considered first. In Fig. 3 the blank part of the circle represents the part of the cross-section occupied by the gas, while the shaded part represents the liquid. As no difference in velocity is assumed, the ratio between the areas of these parts represents at the same time the ratio of the volumes of gas [1] and liquid flowing through the total cross-section.

Should liquid and gas be supplied again in the same ratio as represented by Fig 3, and should there now be a small difference in velocity between the gas and the liquid, then the former will be flowing faster than the latter, and the cross-section occupied by the gas will be smaller than that represented by Fig. 3, owing to the higher velocity, while the cross-section occupied by the liquid will be larger than that represented by Fig. 3, owing to the lower velocity. Consequently, the ratio in which gas and liquid

[1] In this paper the volumes of gas are measured at the pressure prevailing in the cross-section considered.

are present in a certain cross-section can be represented by Fig. 4. The greater the differential velocity between the gas and the liquid, the greater will be the part of the cross-section occupied by liquid and the smaller the part occupied by gas.

Up to now it has been assumed that the gas and the liquid flow through separate channels. The same reasoning also holds good when one component is distributed in the other. Then, also, the liquid will occupy a larger portion of the cross-section than the gas, owing to the differential velocity.

RATIO OF SUPPLY	FIG. 3	FIG. 6	FIG. 9	FIG. 12
LOW DIFFERENTIAL VELOCITY (FOAM CONDITION)	FIG. 4	FIG. 7	FIG. 10	FIG. 13
HIGH DIFFERENTIAL VELOCITY (MIST CONDITION)	FIG. 5	FIG. 8	FIG. 11.	FIG. 14
▭ = GAS ▬ = LIQUID	FOAM CONDITION PREVAILS	FOAM CONDITION PREVAILS	FOAM NOR MIST COND. TENABLE	MIST CONDITION PREVAILS

Consequently, when the ratio of supply is represented by Fig. 3, it may be assumed that the foam condition with the low differential velocity is represented by Fig. 4, while the mist condition would be represented by Fig. 5. Considering Fig. 4, it appears that both characteristics for foam condition are fulfilled, viz., more liquid than gas in the mixture and low differential velocity. As the first characteristic for possible mist condition is more gas than liquid in the mixture, it will appear from Fig. 5 that this condition is not fulfilled, so that with a ratio of supply as represented by Fig. 3, mist condition is impossible.

This means that if equal volumes of gas and liquid are supplied, so that the ratio of supply is 1 : 1, the ratio of the mixture will be smaller than 1 : 1, so that more liquid than gas is present, and consequently the foam condition arises. Thus, up to a ratio of supply which may be even greater than 1 : 1, the first characteristic for foam is fulfilled, viz., there is more liquid than gas in the mixture.

Now suppose the ratio of supply is represented by Fig. 6. Then the same reasoning as for Figs. 4 and 5 can be applied to Figs. 7 and 8, so that here also foam condition is possible, while mist condition is impossible.

When the ratio of supply is represented by Fig. 9, the low differential velocity which is inherent in foam condition would alter the rate of flow into Fig. 10. As here the mixture contains still less than 50 per cent. liquid, foam condition cannot exist.

With the high differential velocity inherent in mist condition, the mixture would be represented by Fig. 11, and as under these conditions more than 50 per cent. of the cross-section would be occupied by liquid, mist condition appears to be also impossible.

Finally, let Fig. 12 be the ratio of supply. By the same reasoning, the conclusion is reached that foam condition is impossible, while mist condition is possible.

Thus, gas and liquid can be supplied in such a proportion that :—

(1) when the small differential velocity inherent in foam would occur, the ratio of mixture becomes such that no foam can exist ;

(2) when the large differential velocity inherent in mist would occur, the ratio of mixture becomes such that no mist can exist.

This means that the ratio in which gas and liquid are supplied may be such that neither the foam nor the mist condition can exist. This is caused by the fact that each condition has two characteristics, but when one of the characteristics of a specific condition occurs the other cannot exist, so that each condition makes itself untenable.

This represents the *unstable* condition. In actual flow the two conditions arise alternately, but immediately each converts itself into the other. The consequence is that gas and liquid tend to segregate and form slugs, or to fill the tube with slugs of mist and foam. This causes fluctuations, which may pass into real heading and surging.

When only liquid is supplied, and gradually an increasing volume of gas is added to it, then at first the foam condition arises, which is stable, With more gas the unstable condition occurs, but with still more gas the mist condition is established, which again is stable.

From the above it follows that in one specific tube each desired condition can be procured by variation of the mixture in which gas and liquid are supplied.

But for a given ratio of supply, by variation of the cross-section of the tube, one condition can be converted, to a certain extent, into the other.

This question will not be elaborated upon. It can only be said that the influence of the differential velocity on the ratio of the mixture becomes smaller when the absolute velocity is increased. The absolute velocity can be increased by making the cross-section smaller, viz., using a narrower tube. Therefore, it is possible that the ratio of supply is such that in a wide tube the differential velocity would be able to create the unstable condition, whereas when a narrower tube is employed the mist condition will arise. Consequently, the new principle gives a means of so designing the string of tubing in oil wells that the unstable condition is avoided.

It may be mentioned that a series of experiments was performed by Mr. W. Tempelaar Lietz to illustrate the theory outlined above, and the three phases of flow, viz., foam, intermittent flow, and mist, were clearly demonstrated.

A moving picture record was made of these experiments.

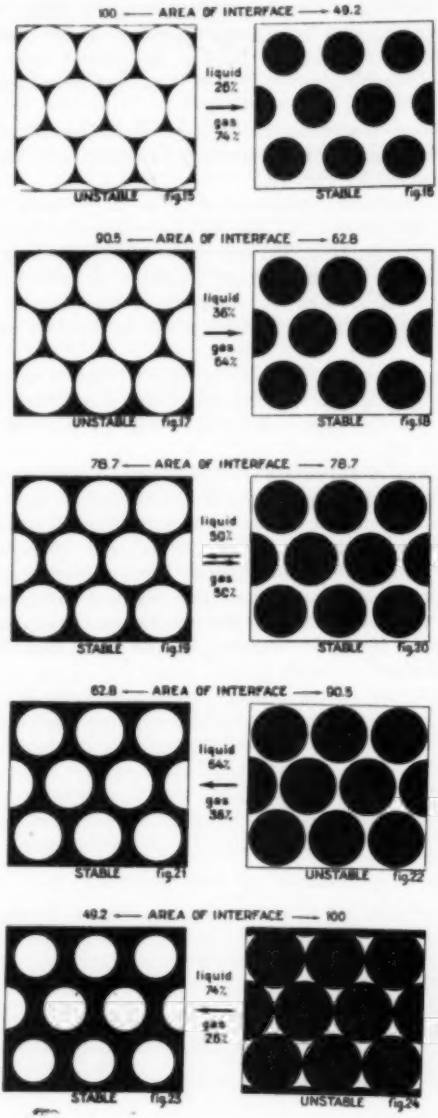
It was assumed earlier in this paper that 50 per cent. liquid and 50 per cent. gas in the mixture is the limit between foam and mist.

An ideal foam can be considered as consisting of a liquid in which spherical bubbles of uniform size are evenly distributed in such a way that the centres of every group of four adjacent bubbles lie in the four corners of a regular tetrahedron. When these gas bubbles expand uniformly they will ultimately touch each other and a cross-section through this foam could be represented by Fig. 15, in which 74·05 per cent. of the volume would be occupied by the gas and 25·95 per cent. by the liquid, or approximately 74 per cent. and 26 per cent. respectively.

If it is assumed that at the moment when the gas bubbles touch each other there are, in a certain volume, n gas bubbles present, then there will also be n places where the liquid has accumulated, filling up the free space between these bubbles. When the gas expands a little more, the gas bubbles will join and form a continuous mass of gas, while the n collecting places of the liquid will form n drops of liquid, so that the moment when the foam is converted into the mist, the same number of drops will be formed as formerly the number of gas bubbles in the foam condition.

In a mixture consisting of gas and liquid there will always be a tendency for it to come to a state in which the area of the interface between the gas and the liquid is smallest, provided there is a disturbing factor but no stabilizer.

Denoting the area of the interface of the foam condition in Fig. 15 by 100, this magnitude will be 49·2 in the mist condition


100 — AREA OF INTERFACE — 49.2
liquid 26%
gas 74%
UNSTABLE fig.15
STABLE fig.16
90.5 — AREA OF INTERFACE — 62.8
liquid 36%
gas 64%
UNSTABLE fig.17
STABLE fig.18
78.7 — AREA OF INTERFACE — 78.7
liquid 50%
gas 50%
STABLE fig.19
STABLE fig.20
62.8 — AREA OF INTERFACE — 90.5
liquid 64%
gas 36%
STABLE fig.21
UNSTABLE fig.22
49.2 — AREA OF INTERFACE — 100
liquid 74%
gas 26%
STABLE fig.23
UNSTABLE fig.24

in Fig. 16 (both figures representing a mixture with 74 per cent. of the volume occupied by gas and 26 per cent. by liquid), so that a foam condition represented by Fig. 15 cannot exist as long as there is any disturbing factor, which is always present in a flowing mixture.

By the same reasoning it appears that the foam condition represented by Fig. 17 has a tendency to change into the mist condition represented by Fig. 18.

The foam condition represented by Fig. 19 contains 50 per cent. of liquid and 50 per cent. of gas, so that when this foam should be converted into mist (Fig. 20) the drops of liquid should have the same size as the bubbles of gas formerly present in the foam. Consequently, the area of the interface is the same in both cases and there is no tendency for the foam to convert into mist or vice versa.

By similar reasoning it can be shown that a mist condition represented by Fig. 22 will be converted into foam represented by Fig. 21, and the mist condition of Fig. 24 into the foam condition of Fig. 23.

Summarizing, it appears that foam can be stable in a mixture in which more than 50 per cent. of the volume is occupied by the liquid, while mist can be stable with more than 50 per cent. gas.

Mixtures containing more than 26 per cent. of liquid and less than 50 per cent. could theoretically form a foam, but this foam would be converted into mist at the slightest disturbance.

A similar reasoning leads to the conclusion that mist conditions with a content of liquid between 74 per cent. and 50 per cent. must be unstable.

The Analysis of Hydrocarbon Oils.*

By R. H. Griffith and H. Hollings.

In a paper concerned with analysis of gas oils,[1] the method employed for separation of naphthene and paraffin hydrocarbons was based on aniline point determinations. At that time, the evidence for the correctness of the necessary assumptions was rather slender, and a much closer investigation of the subject has now been made.

The fact that organic solvents have a selective action on cyclic and open-chain saturated hydrocarbons is, of course, well known. Difficulties arise, however, when an exact interpretation of the behaviour of mixtures is sought. In order to be quite certain of the values involved, the following questions must be answered:—

I. How does the solution point of the paraffin hydrocarbons change as their boiling point rises?
II. What is the form of the same curve for naphthenes?
III. What is the effect of mixing paraffins of different boiling point?
IV. What occurs similarly with naphthenes?
V. How does the addition of naphthenes affect the aniline points of paraffins?
VI. What are the boiling points of saturated hydrocarbons separated from a given boiling point range of a natural oil?

These six points will be dealt with as systematically as possible.

I. In the gas-oil range, little help can be gained from observations on synthetic materials, except perhaps by extrapolations (see later), as these are all in the lower-boiling range. Two sets of curves, however, are available (Fig. 1), and these unfortunately show considerable discrepancies for the aniline points of pure paraffins. [Note: throughout this work the term "aniline point" means the temperature at which equal volumes of oil and aniline become completely miscible. There is considerable confusion on this subject in the literature, but most data given are for "Critical Solution Temperature."[2]]

Preparations of Paraffins.

A mixture of naphthenes and paraffins was prepared from a gas oil by treatment with 98 per cent. sulphuric acid, and various methods of separation were tried.

(1) With *acetone-sulphur dioxide*. Four fractions, b.pts. 250–260° C., 260–270° C., 270–280° C. and 280–290° C., were

*Paper received March 3rd, 1933.

[1] *J.S.C.I.*, 1928, **47**, 30T.

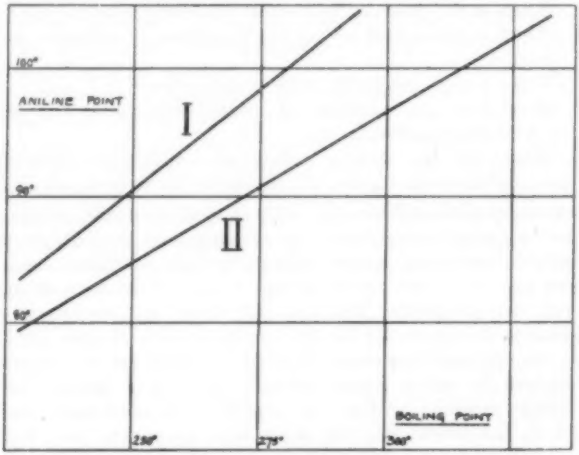
[2] *Institution of Petroleum Technologists.* (Serial No. G30.)

extracted repeatedly with acetone saturated with SO_2 in about equal amount. The original total volume was reduced from 250 ml. to about 60 ml., but the densities were higher, and aniline points lower, than those given for curve II. on Fig. 1. Further treatment did not lead to any improvement.

(2) With *aniline*. Three fractions were examined in detail:—

Boiling Point. °C.	Vol. ml.	No. of extractions at 40°–50°C.	Final vol. ml.	Original density $^{20°}/_{4°}$C.	Final density $^{20°}/_{4°}$C.	Aniline Point. Final.
275–85 ..	73	3	26	0·8132	0·7920	88·7
275–85 ..	26	3	7·5	0·7920	0·7904	90·5
285–95 ..	74	3	25	—	0·8052	90·3
285–95 ..	25	3	8	0·8052	0·7914	91·9
265–75 ..	70	6	9	—	0·7828	89·2

In all three cases, further extraction with aniline failed to alter either the density or the aniline point.



I—Carpenter's data.
II—Griffiths' data.

FIG. 1.

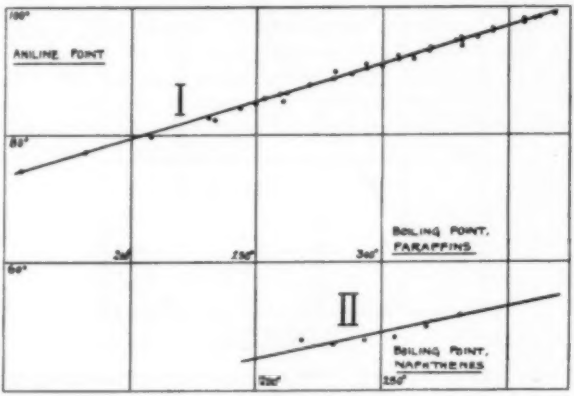
(3) With *sulphuric acid*. Numerous preliminary experiments showed that nitration was not a successful method of removing naphthenes, as the separation was incomplete and the residue always contained nitration products. It was found, however, that an oil which was unchanged by a nitrating mixture would still react with oleum. After repeated washing with this reagent (120 per cent. acid) a colourless oil was obtained. Raw materials

from five different sources were treated in this way, and the dried residue was examined in fractions, as shown in the table :—

Aniline Points of 5 Oleum-washed Oils.

B. Pt. °C.	American (1).	American (2).	Scottish Shale.	Borneo.	Venezuela.
180 ..	—	—	76·3	—	—
200 ..	—	—	79·1	—	—
220 ..	—	—	82·0	—	—
240 ..	—	85·0	85·0	85·1	84·8
260 ..	89·2	88·4	88·0	88·0	87·8
280 ..	91·6	90·8	90·7	90·9	90·7
300 ..	94·1	93·7	93·4	93·6	93·6
320 ..	96·6	97·4	—	96·7	96·8
340 ..	99·3	—	—	99·5	99·9
360 ..	—	101·3	—	—	—

These are shown on the curve, together with the points obtained by aniline extraction ; the agreement is excellent. (Fig. 2.)



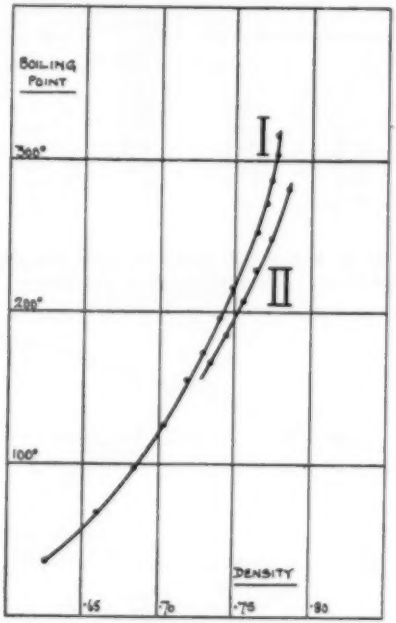
I—Paraffins.
II—Naphthenes.

FIG. 2.

It remains to consider the evidence that these oils are really free from cyclic hydrocarbons. Attention was given to the oil from Scottish shale, and the relation of boiling point to density was determined ; (Fig. 3) these densities are higher than those recorded for synthetic normal paraffins, but may well contain isomers. It is interesting to note that a recent paper[3] discloses that naturally occurring paraffin waxes are not necessarily normal isomers, and the densities recorded by these observers are higher than those of the corresponding n-paraffin. It is, therefore,

[3] Ferris, Cowles and Henderson, *Ind. Eng. Chem.*, 1931, **23**, 681.

extremely likely that all the five oils examined contain both normal and branched-chain compounds, but are free from cyclic hydrocarbons.



I—Normal paraffins.
II—Mixtures obtained.

FIG. 3.

Densities of Residual Oils from Shale.

Boiling point	..	165	185	207	227	248·5	270
Density $^{20°}/_{4°}$C.	..	0·7344	0·7440	0·7552	0·7643	0·7750	0·7832

It is unfortunate that aniline point data are not available for the waxes described above; evidence such as this would probably account for the higher values recorded by Carpenter. There can be no doubt, however, that vigorous treatment with oleum, or repeated extractions with a solvent such as aniline, give a residue of the same composition.

II. A paraffin-naphthene mixture was isolated from a Borneo gas oil. Preliminary experiments were devoted to attempts to extract the cyclic compounds with aniline, but it was found that

the solubility of the higher-boiling fractions was inconveniently low, and that separation of aniline by fractional distillation was very difficult. This would have necessitated washing away the aniline with dilute acid, and would have been very laborious. Extraction with acetone-sulphur dioxide was eventually adopted; the oil was dissolved in acetone, and the solution then saturated with SO_2 so that an oil was thrown out and could be drawn off.

Seven fractions of the paraffin-naphthene mixture were used: b. pts. 220–245°, 260–270°, 270–280°, 280–290°, 300–310°, 310–320° and 320–335°. At first, an equal volume of oil and acetone gave a solution which was then treated with SO_2; the lower layer contained the naphthene concentrate. In some cases it was convenient to warm the oil with the SO_2-acetone, but it was often difficult to obtain solution in this way below the boiling point of acetone. Later, it was found more profitable to use smaller quantities (20 per cent. by vol.) of solvent a greater number of times. The number of extractions actually carried out was approximately 60 for each fraction and between 500 and 600 in all; the original volumes dealt with were about 70–80 ml. in each case, and the combined product was 60 ml. This was dried and distilled, the fractions being examined for aniline point and density. (See Fig. 2.)

Naphthenes obtained by Extraction.

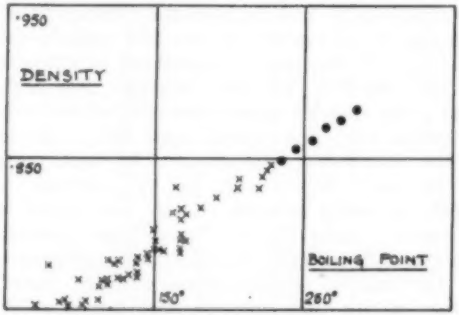
Boiling Point.	Density $^{20°}/_{4°}$	Aniline Point.
230–240 ..	0·8494 ..	47·7
240–250 ..	0·8568 ..	47·0
250–260 ..	0·8624 ..	47·2
260–270 ..	0·8713 ..	47·7
270–280 ..	0·8759 ..	49·6
280–290 ..	0·8821 ..	51·5

The densities agree reasonably with those for recorded naphthenes. (Fig. 4.)

The precise procedure was as follows: A paraffin-naphthene fraction was mixed with acetone, if necessary with warming, to give a solution which was then saturated with SO_2 and cooled to room temperature. Of the two layers which separated, the lower contained dissolved naphthenes, and the acetone was driven off by warming. The remaining oil in the upper layer might be extracted a second time or might be rejected altogether.

For example, an original mixture, b.pt. 245–260° was 72 ml. in volume, A.pt. 78·8°. It was extracted with eight successive portions of 20 ml. of acetone–SO_2 to give 17 ml. of product with A.pt. 48·0° and density $0{\cdot}8700\,^{20°}/_{4°}$. The residue was also extracted seven times with 20 ml. amounts of solvent, and gave a further 16 ml. of product, A.Pt. 58·8° and density $0{\cdot}8402\,^{20°}/_{4°}$. These two

products were united and again extracted ten times with 10 ml. batches of acetone–SO_2. The final 16 ml. had A.pt. 45·5° and density 0·8707 $^{20°}/_{4°}$. (The rejected material was 16 ml., A.pt. 70·4°, density 0·8160 $^{20°}/_{4°}$.)



×—Recorded naphthenes.
●—Naphthenes prepared.

FIG. 4.

The refractive indices, measured with an Abbé refractometer with white light and compensator were as follows:—

Boiling Range °C.	Temperature. °C.	Refractive. Index.
Paraffin Fractions.		
160–180	20	1·4170
180–200	20	1·4208
200–220	20	1·4254
220–240	20	1·4301
240–260	20	1·4346
320–340	25	1·4578
Naphthene Fractions.		
230–240	20	1·4670
240–250	20	1·4786
250–260	20	1·4830
260–270	20	1·4866
270–290	20	1·4903

III. and IV. Two paraffin fractions were first used: (A) boiling below 160°, density 0·7292, aniline pt. 72·5; (B) b.pt. 260–310°, density 0·7862, aniline pt. 91·3°. The mixtures prepared were as follows:—

Ml. of A	0·504	0·996
Ml. of B	1·98	1·98
Observed aniline point	87·4°	85·1°
Calculated aniline point	87·4°	85·1°

A second mixture was made up containing 2·95 ml. boiling from 220–240 (A.pt. 83·6), 2·96 ml. boiling from 240–260 (A.pt. 86·8°)

and 2·92 ml. boiling from 260–310 (A.pt. 91·3°). The observed aniline point was 87·2°, and that calculated 87·3°. There is no doubt that a straight forward mixture relation holds over this range of boiling point.

Similarly with the naphthenes, a mixture was made as follows :—

Boiling Point °C.	Ml. used.
230–240	1·01
240–250	0·997
250–260	1·95
260–270	0·944
270–280	1·065
280–290	0·978

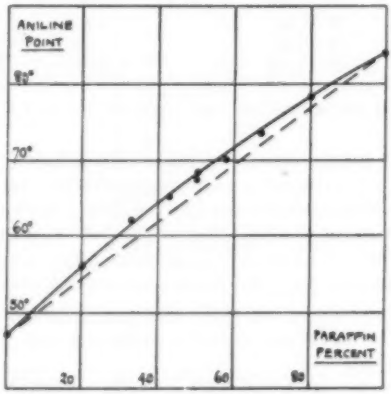
The observed aniline point was then 48·3°, and that calculated was 48·2°.

V. As shown by the curves on Fig. 2, the difference between the aniline points of a paraffin and naphthene of the same boiling point is about 36·5° at 200° and 43·0° at 350° ; it therefore appears that the lowering of 0·4° for 1 per cent. of naphthene is a very reasonable figure. To test this point thoroughly, artificial mixtures have been examined, prepared from collective oils already described.

Ml. Paraffin.	Ml. naphthene.	% paraffin.	Ml. aniline.	Aniline Points. Obs.	Calc.	Diff.
Mixture A.						
1·99	—	100	1·95	85·0	—	—
	0·485	80·4	+0·51	78·1	77·5	0·6
	+0·50	66·8	+0·495	73·5	72·6	0·9
	+0·47	57·8	+0·505	70·4	69·0	1·4
	+0·51	50·3	+0·505	67·7	66·0	1·7
Mixture B.						
—	1·97	—	1·96	47·1	—	—
0·49	—	19·9	+0·50	56·2	54·7	1·5
+0·49	—	33·4	+0·495	62·5	58·8	1·7
+0·525	—	43·3	+0·505	65·6	63·4	2·2
+0·50	—	50·4	+0·505	68·1	66·1	2·0
Mixture C.						
1·975	—	100	1·98	87·2	—	—
—	0·510	79·5	+0·5	79·6	79·4	0·2
—	+0·492	66·4	+0·505	74·9	73·9	1·0
—	+0·496	56·9	+0·49	71·8	70·4	1·4
—	+0·515	49·6	+0·51	69·4	67·6	1·8
Mixture D.						
—	1·94	—	1·96	48·3	—	—
0·495	—	20·3	+0·50	57·3	56·3	1·0
+0·522	—	34·4	+0·54	63·8	61·7	2·1
+0·510	—	44·0	+0·45	67·4	65·4	2·0
+0·490	—	51·0	+0·51	70·0	68·2	1·8

The greatest divergence from the calculated value appears at about 40 per cent. paraffin (see Fig. 5). The errors introduced

into the calculations of composition due to this discrepancy are small; with an oil containing 50 per cent. naphthenes and 30 per cent. paraffins, for instance, the error in aniline point would be 2°, and the error in analysis would be about 2 per cent. For very accurate work on narrow fractions, it might be possible to make corrections to the observed aniline points by graduated subtractions of a small amount, but for ordinary purposes this procedure cannot be recommended.



Full line—observed curve.
Broken line—theoretical curve

FIG. 5.

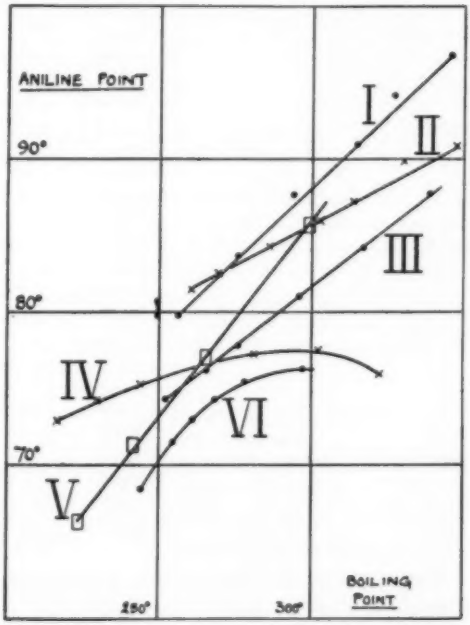
VI. The mean boiling points of paraffin-naphthene mixtures separated from five different sources, have been determined in order to see whether boiling point data for the original oil may be used for calculations on the residue. It can be seen that the assumption is quite legitimate and that no serious error is introduced.

Oil.	Mean Boiling Point. °C.	Paraffin-naphthene Mean Boiling Point °C.
Borneo	288·5 ..	288·5
Venezuelan	287 ..	285
Cracked Oil 1	235 ..	235
Cracked Oil 2	240 ..	236
Rumanian	315 ..	315

The determinations were all carried out as previously described, and the differences make negligible errors in calculations.

Aniline Points of Crude Oils.

In a study of the change of aniline point with boiling point, a number of fractions have been examined from different oils which have not in any way been treated chemically. It was found that with a natural oil, the aniline point rises regularly as the boiling point increases, but that with a cracked oil a maximum aniline



I—Borneo.
II—American.
III—Venezuelan.
IV—Cracked oil.
V—Hydrogenated L.T. tar.
VI—Cracked oil.

Fig. 6.

point is observed before the highest boiling point is reached. In Fig. 6 these results are shown, as well as in tabular form. This provides an interesting criterion of the history of an oil, and is evidently due to the greater instability of the higher paraffins. The test, however, fails to indicate that an oil is a hydrogenation product, such as that obtained from a low-temperature tar.

Aniline Points of Gas-oil Fractions.

Oil.	Mean Boiling Point of fraction. °C.	Aniline point. °C.
Cracked oil (1)	215·0	72·6
	227·5	73·9
	242·0	75·0
	262·5	76·1
	302·5	77·0
	322·5	75·6
Cracked oil (2)	242·5	69·0
	259·0	72·5
	278·5	75·6
	297·5	75·8
Borneo oil	255·0	79·5
	275·0	83·4
	295·0	87·6
	315·0	90·8
	348·0	96·6
Venezuelan oil	255·5	74·4
	275·0	77·4
	317·5	83·6
	337·5	87·0
Rumanian oil	260·0	81·1
	285·0	84·0
	315·0	87·0
	350·0	90·4
	365·0	91·5
Hydrogenated L.-T. tar, gas-oil fraction	221·5	65·9
	240·0	71·0
	265·0	76·1
	300·0	85·4

Improvements in Analytical Technique.

A great saving in time of analysis can be effected by adoption of a suggestion made by Dr. F. H. Garner that the residual oil, after washing with strong sulphuric acid, should not be treated with water and alkali, but used as it is for aniline point determinations. The results are not in any way affected by this process, provided that no acid is carried into the aniline with the oil.

A searching examination has been made as to the accuracy with which different experimenters can carry out an analysis. It may be noted that care must, of course, be given to calibration of thermometers, and that the aniline employed must be perfectly dry. For the purpose of checking fresh supplies, a large sample of any dry gas oil will suffice for several years. Analytical results

obtained in repeated measurements on six different oils are given in the following table :—

		Unsaturated. %	Aromatic. %	Naphthene. %	Paraffin. %	Mean Boiling Point. °C.	Aniline point. °C.	Valuation.
Sample	A, 1 ..	5·0	23·8	13·4	57·8	268	81·5	62·8
	A, 2 ..	3·0	21·8	13·5	61·7	268	81·8	64·7
	B, 1 ..	5·0	34·4	23·2	37·4	243	67·7	42·4
	B, 2 ..	7·0	34·9	22·8	35·3	243	67·3	42·3
	C, 1 ..	1·5	21·2	12·2	65·1	284	84·6	66·6
	C, 2 ..	2·0	22·1	11·2	64·7	280	84·5	66·7
	D, 1 ..	5·0	84·5	10·5		281	—	—
	D, 2 ..	3·0	87·8	9·2		272	—	—
	D, 3 ..	5·0	87·8	7·2		280	—	—
	E, 1 ..	1·0	11·9	7·8	79·3	298	89·4	80·3
	E, 2 ..	2·0	12·7	8·5	76·8	294	88·2	78·8
	F, 1 ..	6·0	21·6	15·0	57·4	280	82·0	63·4
	F, 2 ..	6·0	21·6	14·7	57·7	280	82·2	63·7
	F, 3 ..	5·0	21·7	15·0	58·3	279	82·0	63·3

It is found of extreme importance that shaking with sulphuric acid should always be vigorous and carried out rigorously under the conditions prescribed. It has also been found useful, in redistilling the residual oil after treatment with 80 per cent. sulphuric acid, to add a definite volume of the original residue from the initial distillation. This prevents the flask becoming dry in cases where nearly the whole oil is volatile ; a volume of 2 ml. is generally available for this purpose.

The Strength of Sulphuric Acid for Removal of Aromatic Hydrocarbons.

Four samples of sulphuric acid were prepared and analysed. A normal gas oil, mean b. pt. 288°, was distilled and treated with 80 per cent. sulphuric acid, and the residue was re-distilled according to standard practice. The results were as shown below :—

Strength acid. %	Unsaturated. %	Aromatic. %	Naphthene. %	Paraffin. %	Aniline Point. °C.	Valuation.
96·96	4	14·4	16·3	65·3	82·7	69·3
97·97	4	19·2	10·7	66·1	85·9	70·1
99·70	4	20·6	9·5	65·9	86·5	69·9
100·80	4	21·6	8·9	65·5	86·8	69·5

It is clear that the total cyclic hydrocarbons, and hence the " valuation number "[4] are practically unaffected by acid strength over this range. No decision can be made, or is necessary, as to the point at which most complete removal of aromatic compounds occurs without any loss of naphthenes. The change between 98 and 100 per cent. is very small.

[4] *J.S.C.I.*, 1929, **48**, 252T.

Summary.

Paraffins and naphthenes have been isolated from the gas-oil fraction of a number of oils. It is found that the portion insoluble in oleum corresponds with that which is least soluble in aniline, and the term " paraffins " is applied to the component substances.

The aniline point-boiling point curves for the isolated paraffins and naphthenes are given, and their mutual effect on each other's aniline points has been determined. It is found that the previous assumption of a lowering of 0·4° for 1 per cent. naphthene is perfectly satisfactory, as the disturbing factors do not influence the analysis beyond the limits of experimental error.

Aniline point-boiling point curves for crude oils are suggested as a criterion of their previous treatment; those which have suffered partial cracking give curves, while those which are uncracked give straight lines.

No alteration is suggested in the original analytical methods on which the valuation of gas oils was based. A few improvements in technique are described, and typical results are given for tests carried out by separate observers.

In view of these results, there appears to be no reason to alter the conclusions already arrived at concerning the gas-making value of different components. Although it has been suggested that the naphthenes may contribute a large share of the therm yield,[5] the analytical data previously presented[6] show no relation between the total saturated hydrocarbons and the therm yield, The agreement is no better if the valuation suggested (*loc. cit.*) of 25 for unsaturated, 60 for aromatic and 79 for saturated hydrocarbons, is taken for the calculation.

The authors wish to record their thanks to the Directors of the Gas Light and Coke Company for permission to publish this work, which was carried out in their Fulham Laboratories.

[5] Murphy, *Am. Gas Assoc. Proc.*, 1930, 1189.
[6] *J.S.C.I.*, 1929, **48**, 252.

The Performance of High-Speed Diesel Engines for Road Transport as Affected by the Nature of the Fuel.*

By J. G. Withers, B.Sc., A.Inst.P. (Student Member).

During the past few years, the high-speed Diesel engine has developed very rapidly and many designs have appeared which only operate successfully on certain fuels. At the same time the tendency is to develop engine types in which the range of usable fuels is increasing. The purpose of this paper is to study from engine tests the way in which the fuel characteristics may affect the behaviour of an engine. From the conclusions reached it is believed that an indication may be obtained as to how much the fuel is responsible for certain imperfections in the running of high-speed Diesel engines.

An important requirement of a fuel is that it shall not give rise to mechanical trouble in the injection system. It should be free from particles of foreign matter and water likely to choke the filters in too short a time and which may lead to corrosion and wear of the pump plungers, delivery valve seats and atomiser needle valves. The viscosity should be sufficiently low at the lowest working temperature to be pumped without undue loss of head at the suction, and sufficiently high to lubricate the working parts and ensure a reasonable life of the latter. Unduly low viscosity will cause excessive pump and atomiser leakage, with consequent loss of output and in some cases wastage of fuel, these effects increasing with the age of the fuel system moving parts.

In many designs the oil must be delivered into the combustion chamber in a fine and well dispersed spray, air swirl alone being insufficient to ensure good combustion. An oil of unduly high viscosity when injected by a normal type of spring loaded sprayer will give rise to coarse drops with high penetration, neither of which is desirable. The larger drops find greater difficulty in meeting sufficient oxygen for their complete combustion, while the higher penetration of the drops may enable them more easily to reach the combustion chamber and cylinder walls. Any oil striking the combustion chamber walls burns incompletely and may give rise to carbon and smoke, while that reaching the cylinder walls may contaminate the lubricating oil.

A fine, well-dispersed spray is also essential for easy starting when the air swirl is not a major factor in the design.

Following injection combustion must proceed smoothly and efficiently. This implies :—

(1). There shall be a minimum of combustion knock.

* Précis of paper read before Students' Section, London Branch, on December 6, 1932.

(2). The maximum pressure shall be kept within definite limits.

(3). The power output shall be as high as possible.

(4). The volume consumption of fuel per brake horse power developed shall be a minimum.

(5). There shall be absence of exhaust smoke and smell.

(6). A minimum of carbon shall be deposited in the combustion chamber, on the valves, in the ports, and especially in the region of the fuel injector.

The above six factors and the ease of starting depend very largely on the engine design, but the fuel has a definite effect, which may be important.

The experimental work on which many of the conclusions are based was performed on two typical high-speed Diesel engines, details of which are given below.

Engine 1 is a single cylinder L.W. type Gardner engine, developing 19½ h.p. at 2000 r.p.m. This engine has direct injection into an open combustion chamber, most of which is included in the cup shaped piston crown. The compression pressure at 1000 r.p.m. can be either 450 lb. per sq. in. or 550 lb. per sq. in. according to the piston used, the former being the makers' standard.

Engine 2 is a single cylinder McLaren Benz pre-combustion chamber engine, developing 16 h.p. at 1000 r.p.m. The compression pressure under load is 600 lb. per sq. in.

The order in which the various engine characteristics are examined below has no regard to their relative importance, this being governed largely by the type of engine, economic considerations and personal prejudice or local bye-laws.

Combustion Knock.

Combustion noise, whilst being objectionable both to the driver and the public, is also evidence, as will be seen below, that rapid pressure rises and shock waves are present inside the combustion chamber. One result is that the big end bearings may become cracked, with ultimate mechanical failure of the engine. This has been a very common trouble with the high-speed Diesel engine, although, as pointed out by Ricardo, it is difficult to ascribe it to shock alone. Similarly cylinder heads and piston crowns sometimes crack, partly due to temperature stresses and partly due to excessive shock. There is also to be considered the psychological effect on the driver experienced with gasoline engines who would object to a knocking engine.

The relation between the ignition delay and the combustion knock was investigated by means of the Farnboro' indicator and

the Strobophonometer. A number of fuels having a range of delay angles was obtained by blending a long delay and a short delay fuel. The results obtained are given in Fig. 1.

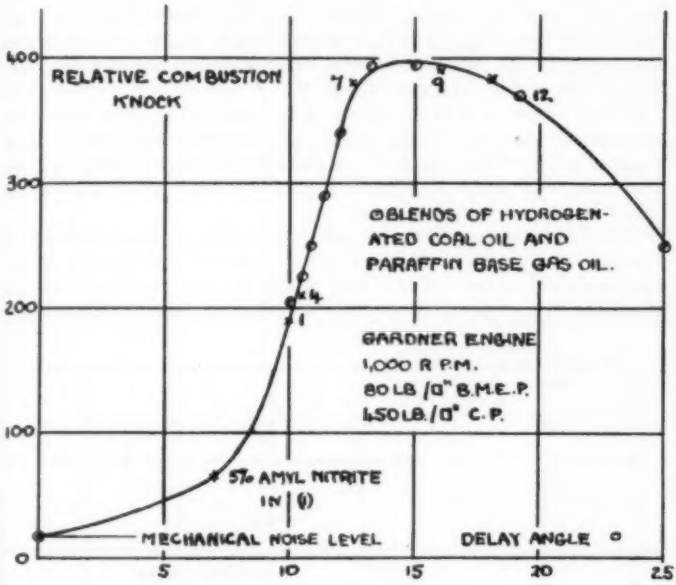


FIG. 1.

It is reasonable to assume that combustion knock is due to the uncontrollable combustion of the first portion of the injected fuel. The drops entering the combustion chamber are distributed into the hot air and begin to warm up. A slow chemical reaction commences and the drops continue to rise in temperature until a condition is reached when rapid combustion sets in, accompanied by a rapid pressure rise. During this delay period, fuel has been injected continuously and will burn in an uncontrollable manner as soon as ignition is started. All fuel injected after the commencement of rapid pressure rise will burn almost as it issues from the nozzle, and the speed of combustion will be governed largely by the contour of the fuel pump operating cam. The longer the delay period the larger will be the amount of fuel burnt in an uncontrollable fashion, that is, the heavier will be the combustion shock. The argument holds up to the point where the delay angle equals the injection angle and this condition corresponds to a maximum

of noise, the combustion of the whole of the injected fuel being out of control. In Fig. 1 the delay angle giving maximum noise corresponds very nearly to the injection angle, which was 16° under the conditions of test. If the delay angle exceeds the injection angle the noise decreases, possibly due to the fact that with these very excessive delays the piston has commenced the downward stroke, thereby relieving the maximum pressure and the noise effect of the explosion wave.

A high viscosity has the effect of increasing the drop size with consequent increase in the delay period since the larger drop requires a longer time to heat up to the self-ignition temperature. The increased delay will have a corresponding small increasing effect on the combustion noise.

It has been assumed that equal volumes of fuel burn with equal rapidity and give rise to the same degree of combustion noise. The chemical nature of the fuel might be expected not only to affect the delay angle, but to have an effect on the rate of combus-

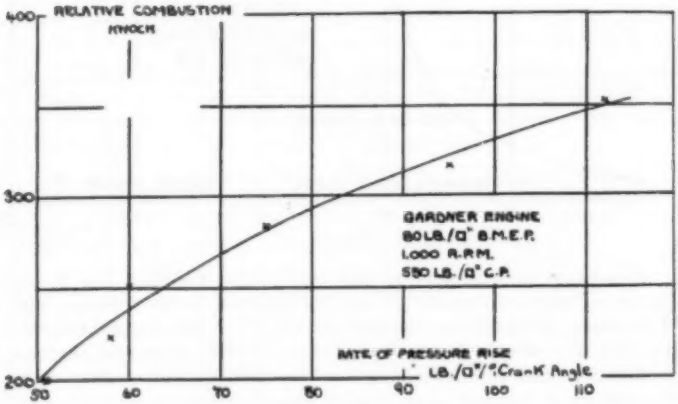


FIG. 2.

tion; also, the specific gravity and calorific value will influence the amount of heat liberated, which would affect the extent of the pressure rise. These factors are shown to be of little importance by the numbered crosses in Fig. 1, which correspond to a widely differing selection of fuels. All of these lie near to the mean curve, even though some represent extreme cases of high and low viscosity and distillation characteristics outside the range of high-speed Diesel fuels.

The delay angle then may be taken as a good guide to the knocking properties of a fuel in an engine, although of course a direct noise measurement under standard conditions would be more reliable.

The rapidity of the pressure rise following the delay period is an indication of the additional stresses that may be imposed on the working parts. It is the extreme rapidity of this pressure rise that gives rise to the shock wave and combustion knock. In Fig. 2 is

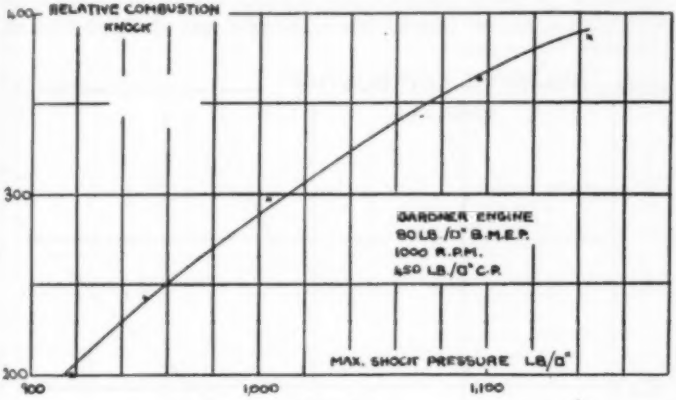


FIG. 3.

shown the experimental relation between the initial rate of pressure rise taken from Farnboro' indicator diagram sfrom the Gardner engine and the combustion knock, the varying degrees of knock being again obtained from blends of a long delay and short delay fuel. In this case the compression pressure was 550 lb. per sq. in.; at 450 lb. per sq. in. the pressure rises on all fuels were far too rapid to be measured accurately.

It was noticed that the maximum pressures recorded by the Farnboro' indicator increased with increase of knock, and the results obtained are given in Fig. 3. Since an increase in knock was accompanied by a longer delay angle, the point of maximum pressure occurred later in the expansion stroke and the maximum pressure should theoretically have been lower instead of higher. It was concluded that the very high pressures recorded were local, and did not represent the mean throughout the combustion chamber. They are probably produced by reflection of the shock wave at the combustion chamber walls. These high shock pressures will

be imposed on the piston crown and cylinder head, and, although local, will throw an additional stress on the engine.

All the tests described above give a fairly reliable estimate of the shock or noise likely to occur in an engine, but by far the best and most accurate method is the direct sound measurement. For a standard knock test, an engine torque, speed and jacket temperature must be selected at which the delay period for the worst fuel to be tested is less than the injection period. The injection period will, of course, be nearly constant for all fuels if the torque is kept constant. A nearly linear relation will then be obtained connecting the delay angle and knock, that is the first part of Fig. 1 without the peak will appear.

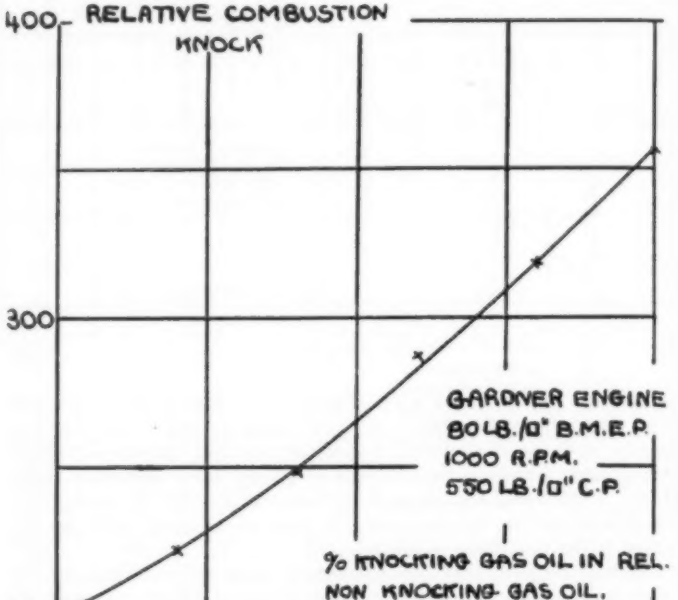


FIG. 4.

Cetene and α-methyl-naphthalene have been selected as provisional standards but, owing to their high price, it is desirable to use calibrated sub-standard fuels for normal testing. Cetene percentages, when plotted against equivalent sub-standard percentages, give a straight line. Fuels can be evaluated in terms of

equivalent cetene blends or sub-standard blends either by bracketing them between two known blends and interpolating the exact equivalent from the Strobophonometer readings, or from a noise curve such as Fig. 4.

Fuel Dopes.

Certain chemical compounds, commonly referred to as "dopes," have the effect of reducing the delay angle and therefore reducing shock. A possible reason is that these compounds, in the presence of hot air, encourage the formation of unstable peroxides of lower self-ignition temperature than the undoped fuel. In Fig. 1 it will be seen how much the relatively non-knocking fuel was quietened

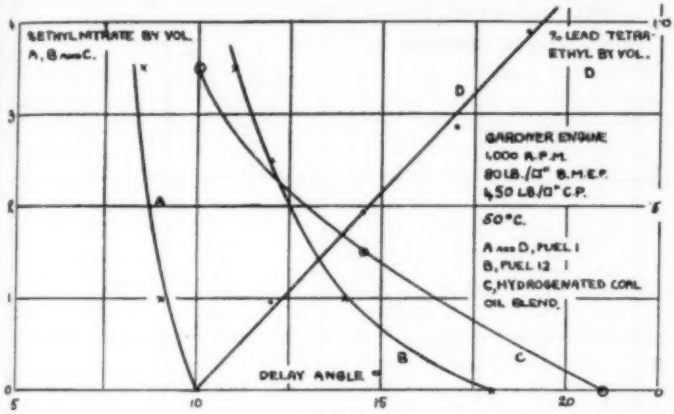


Fig. 5.

by the addition of amyl nitrite. Fig. 5 shows the affect of the addition of various percentages of ethyl nitrate on the delay angle of several fuels. The reverse effect of the pro-knock lead tetraethyl is also shown. As far as the author is aware, none of the anti-knock dopes as yet discovered are nearly effective enough to be economically introduced into a fuel. Small quantities are insufficient to be useful and larger amounts become expensive and begin to affect appreciably the calorific value of the resulting fuel.

Ease of Starting.

Easy starting is a very important quality of a fuel since a large number of engines rely entirely on the compression heat for starting. In cold weather these types require the best of fuel if they are to be started by hand or with a minimum drain on the starter battery. The McLaren Benz engine was used to examine the starting quality

of fuels. Fig. 6 shows a mean curve connecting the delay angles, and the limiting starting temperatures, and indicates that the ease of starting is largely dependent on the properties which give smooth combustion. Several points are off the curve to a greater extent than the experimental error, which is to be expected, since the limiting starting temperatures are dependent on the quality of the spray. This effect is shown in Fig. 5 by fuel 19, a fuel of high viscosity, which has a higher limiting starting temperature than would be expected by its delay angle.

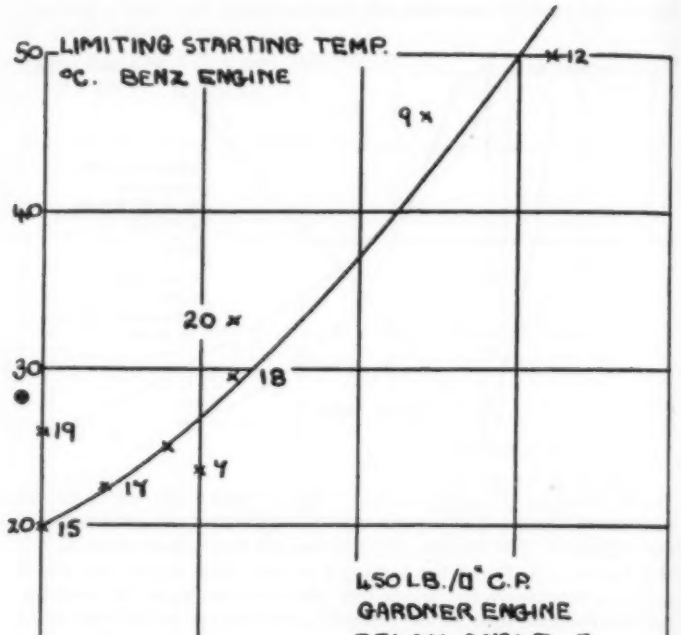


FIG. 6.

It appears from these tests that a fuel which gives smooth running under operating conditions will be an easy starter unless it is too viscous when cold to be handled by the pumps and atomisers.

Contamination of the Lubricating Oil.

From calculated values of the spray velocity it appears that, even in the case of the best fuels, the delay period is sufficiently long to enable fuel to reach the combustion chamber walls. The longer the delay period, the greater will be the risk of serious contamination of the lubricating oil.

Fuel Consumption.

Since economy in fuel consumption is one of the greatest advantages the Diesel engine shows over the gasoline engine, it is of great importance that this advantage should be maintained in view of possible taxation of Diesel fuel. Provided that the viscosity is sufficiently low to give good atomisation, that the delay angle is not too long, and that there are no very heavy ends which will not burn completely, then, for all high-speed Diesel fuels the power outputs at a given setting and the consumptions in pounds of fuel per brake horse power hour developed will agree within very close limits. This latter is shown in Table I., giving consumption

Table I.

Gardner Engine at 1000 *r.p.m.* 80 *lb./sq. in. B.M.E.P.*

Fuel No.	Delay Angle.	Relative Consumption.	% Distilled to 350° C. Atmospheric Distillation.
1	10°	100·0	89·0
2	10°	100·75	79·0
3	10°	101·5	72·0
4	10½°	104·0	42·0
5	11°	98·75	96·5
6	11½°	99·0	96·5
7	12½°	99·25	93·0
8	12°	100·75	91·5
9	16°	102·5	89·5
10	15½°	100·75	95·0
11	13½°	103·5	55·0
12	18°	103·5	72·5

tests with delay angles and distillation figures for various fuels on the Gardner engine. The engine was run at 80 lb. per sq. in B.M.E.P. and 1000 r.p.m. The consumption figures are reduced to percentages, the standard smooth running fuel being 100. Fuels No. 9 and 12 have excessive consumptions owing to their long delays, and No. 4 and 11 owing to their high percentage of heavy ends and high viscosity.

Exhaust Smoke.

The tendency of some engines to give exhaust smoke has been a frequent source of adverse comment and immediately attracts the attention of the general public and the police. It is important, therefore, to determine how far smoke depends on the fuel. Black sooty smoke is obviously due to incomplete combustion, and

TABLE II.

Chemical Data of the Fuels Tested.

Fuel No.	Sp. gr.	Viscosity centistokes at 32° F.	Viscosity centistokes at 70° F.	Viscosity centistokes at 100° F.	Fl. Pt. (PM.) ° F.	Set Pt. °F.	Car. Res.* %	Cal. Val. gross B.Th.U./lb.	Sulphur %	Sediment %	Distilled to 350°C Atmos. press. %
1	0·867	19·46	8·46	5·2	236	8	0·06	19,500	1·07	0·003	88
2	0·870	—	12·49	7·35	226	12	0·81	19,450	1·17	0·004	70
3	0·877	78·56	17·78	9·87	220	22	1·65	19,390	1·27	0·006	72
4	0·896	—	56·59	23·18	190	37	3·73	19,280	1·41	0·008	42
5	0·833	7·35	4·25	2·95	182	12	0·01	19,700	0·54	0·007	96·5
6	0·852	8·4	4·53	3·07	188	0	0·01	19,800	0·65	0·009	96·5
7	0·867	13·79	6·4	4·03	184	bel. −20	0·02	19,700	0·11	0·007	93
8	0·855	12·97	5·99	3·96	208	−10	0·17	19,675	0·63	0·008	91·5
9	0·896	13·35	6·24	4·12	184	bel. −20	1·09	19,300	1·01	0·002	89·5
10	0·904	15·28	6·53	4·12	206	bel. −20	0·13	19,150	0·50	trace	93
11	0·910	118·3	29·64	14·07	202	bel. −20	0·17	19,220	1·62	0·011	55
12	0·929	—	20·19	10·14	178	−2	0·50	19,250	0·16	[0·016	72·5
15	0·840	—	5·72	3·71	200	7	0·02	19,750	0·63	0·003	88
16	0·859	—	3·65	2·58	196	bel. −20	0·02	19,750	1·44	0·003	FBP 312
17	0·857	—	5·2	3·49	188	−3	0·04	19,700	0·27	0·003	93
18	0·865	—	3·84	2·62	188	−16	0·01	19,500	1·01	0·002	FBP 349
19	0·885	—	26·0	14·0	186	28	2·79	19,400	1·34	0·014	57
20	0·887	—	6·4	4·17	210	34	0·03	19,250	0·14	0·011	88

* Conradson.

occurs at high brake mean effective pressures and high engine revolutions. Smoke can largely be eliminated by suitable engine design, but any engine will give a black exhaust if sufficient fuel is admitted. In present designs usually not more than about 80 per cent. of the air charged can be burnt without smoke, and the problem becomes increasingly difficult as the rotational speed increases. The smoke point may set the upper limit of B.M.E.P. for an engine, the fuel pump having to be adjusted so that it cannot deliver more fuel than would give a tolerable exhaust. Thus, any improvement in the fuel which would give more smoke margin would immediately enable a higher output to be carried. In order to explore the effect of fuel change, tests were carried out in the Gardner engine at all loads, at speeds up to 2000 r.p.m., at steady speed and both accelerating and stalling, and over a range of jacket temperatures. No differences were detected between marketed high-speed Diesel fuels, and even heavy residue and lubricating oil used as fuel gave satisfactory performance. There has been a general opinion that since the long delay fuels burn more rapidly than the short delay fuels, they burn more completely and therefore with less smoke. The bench tests made by the author, and observations on a large fleet of Diesel-engined 'buses on the road, have not confirmed this view. Ignition delay appeared to have no effect on exhaust smoke, except in the case of fuels with ignition delay sufficiently long to cause a reduction in the rate of burning and pressure rise, in which case the smoke was worse. The only case where a definite improvement in the smoke was effected was when kerosine and motor spirit were run in the engine. In these examples a large percentage of the fuel may be

vapourised and also the drops will be smaller with less penetration, both of which effects would account for an improvement. Even so, the difference was very small and not of practical value ; it was only sufficient to enable a very small percentage more output to be carried. Excessive lubricating oil in the combustion chamber gave black smoke similar to over-load smoke and not blue smoke, as in the case of a gasoline engine.

Blue smoke seems generally to be caused by unburnt fuel mixing with the hot exhaust gases. A number of oils were tested, in boiling range varying from motor spirit up to heavy residue and lubricating oil. The procedure was to inject a measured quantity of oil into the exhaust pipe and estimate the intensity of smoke from the opinions of several observers. Very little difference could be detected, but the more volatile fuels had the advantage.

The question then arises, under what conditions will fuel be deposited in the exhaust system and in what way does this depend on the fuel. When idling on the governor, most multi-cylinder Diesel engines blow a certain amount of fuel into the exhaust system which does not immediately appear as smoke, since the exhaust temperature in this condition is low. The smoke will appear when the engine is put on to load, that is, when accelerating. The longer the delay angle of the fuel, the less certain is ignition, and consequently the more chance there is of fuel finding its way into the exhaust in the idling condition. From observations on the Gardner engine, after a period of idling when running on different fuels, the conclusion reached was that both the short delay and the more volatile fuels gave less blue smoke.

Regular Idling.

With long delay fuels, at low loads, ignition is often irregular, and this gives rise to an unpleasant vibration, which is most noticeable inside a public service vehicle. Owing to cooling of the combustion chamber walls and the lower compression pressure at the slower running speed, there is insufficient margin of temperature to ensure regular ignition if the delay period is over long.

Exhaust Smell.

Tests made by the author with several observers have shown no consistent differences in the exhaust smell of a given engine when run on different fuels. In a particular case six fuels were tested with sulphur content varying 0·2 to 2 per cent. The observers differed greatly in the order in which they placed the fuels, and it did not appear that the sulphur content had a material effect on the unpleasantness of the smell.

Deposition of Carbon.

Very few modern engines form carbon when under load, but the accumulation of deposits may be serious if the engine is run light or idling for any length of time. Carbon formation in hot places, such as under the exhaust valve heads, near the atomiser, and in the ports of 2-stroke-cycle engines, examined after short tests, appeared to follow the carbon residue test. Very little research appears to have been done on the causes of carbon formation generally, and no definite conclusions can be arrived at. Fuels with very heavy ends leave a tarry residue at light loads, which burns slowly, forming hard carbon. In some engines this takes the form of a ring or cone round the atomiser, which builds up to a certain height and then breaks off. The broken pieces are liable to be held under the exhaust valve causing the engine to fail entirely, due to loss of compression, if a single-cylinder engine, and to run badly for some time if a multi-cylinder engine. The consequence is very serious pitting of the exhaust valves. Piston ring sticking is not generally attributable to the fuel and seems to be common only with certain 2-stroke engines, but fuels may be a contributory cause. Carbon deposits on an average are not nearly so extensive in Diesel engines as in gasoline engines, since lubricant getting into the combustion chamber can be burnt more completely.

Conclusions.

1. For silent running, easy starting, absence of shock loading, with its possible damaging effects on the working parts, and good idling, a fuel of short delay or good ignition quality is desirable.

2. As high a specific gravity as possible consistent with short delay and reasonable distillation range and as high a calorific value as possible are required to ensure maximum power and miles to the gallon. (In general the delay angle increases with higher specific gravity.)

3. Heavy tail ends should not be present if a clean exhaust under all conditions is desired.

4. The carbon residue test must be as low as possible to avoid internal carbonisation in the poorer designs of engine.

5. The viscosity must be sufficiently low to meet the coolest conditions likely to occur in the pump system, and sufficiently high for the oil to be pumped with small leakage and to give lubrication for the working parts of the injection system.

6. The fuel must be free from foreign matter.

The author wishes to thank the directors of the Anglo-Persian Oil Company for permission to publish the results of research carried out in the Engine Research Branch of the Company.

Railway Traction in Relation to the Oil Industry.*

By G. M. Barrett, B.Sc. (Student).

The paper dealt with the various methods of utilising oil fuel which have been tried by the railways of this country, with a few references to interesting foreign developments.

Steam Locomotives Burning Oil Fuel.

The Great Eastern Railway introduced oil-firing into this country in 1890, using the residue left over from the manufacture of oil-gas for carriage illumination.

The chief mechanical engineer devised a special steam-jet burner with gravity feed from the oil tanks in the tender, and the result was so successful that Russian and Borneo oils were purchased to increase the supply in order to fuel about sixty express locomotives. In the early years of the present century the price of fuel oil rose until oil-firing was no longer as economical as coal, while the gas-oil residue fell off owing to the introduction of electric lighting in the trains, so the locomotives were re-converted to coal firing.

Since then oil fuel has only been used in this country during coal strikes, the railway companies keeping a considerable number of oil-burning sets in readiness for equipping a certain number of locomotives in case of coal stoppages.

The Southern Pacific Railroad in U.S.A. run most of their largest locomotives on oil fuel, large horse-powers being necessary to climb the heavy gradients in the Rocky Mountains.

Oil-firing is also used in Rumania between Brasov and Ploesti over the Predeal pass in the Carpathians, and in the Argentine, where four of the British-owned railways jointly possess their own oilfields for producing their fuel requirements.

Advantages.—(1) Less weight of fuel carried owing to higher calorific value.

(2) More perfect combustion, less tendency to smoke and soot so that the trains keep cleaner.

(3) Fuel burns with continuous supply, instead of in batches, which necessitate frequent alterations of the air supply as with coal.

(4) Horse powers can be used which with coal would need automatic stoking, and in any case the fireman has more time to help the driver in observing the signals.

(5) Shorter time to refuel after a run, and fire does not need cleaning out.

(6) Firetubes do not choke up so quickly.

* Précis of paper read before the Student Section, London Branch, on March 6th. 1933.

Disadvantages.—(1) Higher cost of fuel per B.Th.U. in England.

(2) Tendency for the brick arch to fuse after a time.

(3) Despite the concentration of heat at the front of the firebox, the back corners remain comparatively cold so that there is less effective heating surface.

The Gasoline Engine.

Owing to the high cost of gasoline compared to other fuels, the gasoline engine has only a very limited scope for railway work. Motor railcars are mainly used for light railways and steam tramways in country districts where traffic is light and axle loads are limited. On the grouped railways, for ordinary work, there is nothing the gasoline engine can do which cannot be done as well and more cheaply by steam or C.I. engines.

There is one development which has arisen recently which should have a successful future in its own particular sphere of usefulness. This is a convertible road-rail vehicle designed by the L.M.S. Rly., which can run on either road or rails. The flanged rail wheels of pressed steel are fixed directly on to the front and rear axles for the standard railway gauge. The pneumatic tyred road wheels are mounted on eccentrics fitted to outer extensions of the rail wheel axles.

When running on the road, the road wheels are locked in position concentric to the axle and revolve together with the rail wheels, which being of smaller diameter do not touch the ground. To transfer to the rails, the vehicle is driven on to a ramp sloping gradually below rail level, so that the rail wheels come into contact with the rails and take the load, the road wheels then being raised by half a turn of the eccentric mounting and locked. The change-over can be effected in two and a half minutes. A supplementary gearbox is provided to give a smaller gear ratio when running on rails. The system can be applied to any type of motor vehicle, either passenger or goods.

For passenger traffic such vehicles can be used for combined rail and road tours, and for branch lines where the terminus is inconveniently distant from the town it serves.

From the point of view of goods traffic, the load can be actually carried door to door without transferring it in part or in bulk.

The Compression-Ignition Engine.

The first large locomotive to use the C.I. engine was built on the Still principle. It had eight double-acting cylinders, with steam working on the piston-rod side and compression-ignition on the other. The drive was transmitted from the crankshaft by

reduction gearing to the jackshaft which was connected to the coupling rod by a crank, and thence to the coupled driving wheels.

Steam was used for starting, overload, creating the vacuum for the train brake, applying the locomotive steam brake and for train heating, while internal combustion was employed for continuous work. The locomotive was tried experimentally on the L.N.E. Rly., but no more were built. It had advantages over the usual C.I. engine in that it was directly geared to the wheels without variable transmission, but presumably the fuel savings did not justify the expense of providing two forms of prime movers.

When the I.C. engine is used alone in locomotives or railcars, there must be a variable transmission of some sort, and the only two forms which have stood the test of practical use are the hydraulic and electrical systems.

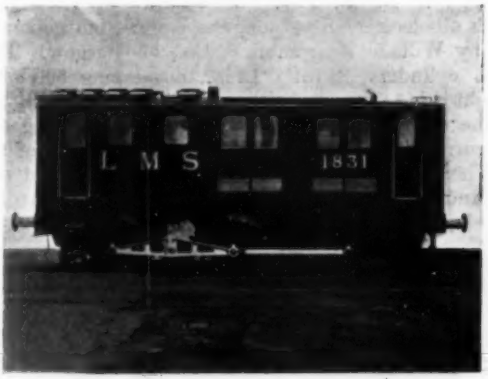


FIG. 1.

FIG. I. shows an I.C. engined shunting locomotive, which was constructed by the L.M.S. Rly. at their Derby works. A 6-coupled steam shunting tank engine was rebuilt with C.I. propulsion fitted to the original chassis.

The heavy oil engine, supplied by Davy Paxman & Co., of Colchester, is a 6-cylinder, 4-stroke solid-injection, rated at 400 b.h.p. with a normal running speed of 750 r.p.m. The transmission is a hydraulic coupling, the pumping unit being direct coupled and capable of absorbing 400 b.h.p. continuously at 750 r.p.m., while the transmitter unit is capable of infinite variation in speed, in either direction, from zero up to a speed equal to 25 m.p.h. on the locomotive, with a corresponding torque ratio of

1 to 5. Controls are provided at both sides of the forward and rear driving compartments.

The air compressor is a 5 h.p. 2-stage unit, charging the main reservoirs at 300 lb. per square inch.

Advantages.—(1) High efficiency of transmission, normal power wastage being only 5 per cent. to 10 per cent., which is less than with electrical transmission.

(2) Comparatively cheap owing to small b.h.p. required to give a large torque at low speeds.

(3) Very flexible in operation.

(4) No standby losses as in steam shunting locomotives, while it is capable of continuous use all through the 24 hours.

Disadvantages.—400 b.h.p. is about the limit which can be transmitted by this method.

In 1928 the L.M.S. Rly. ordered an experimental 4-coach train with oil-electric propulsion, the engine and generator being supplied by William Beardmore & Co., of Glasgow. The engine has eight cylinders, $8\frac{1}{4}$ in. $\times$ 12 in., developing 500 b.h.p.; the train weight is 144 tons, giving a power/weight ratio of $3\frac{1}{2}$ b.h.p./ton. The engine set is located in the front of the leading coach and supplies current to the motors on the leading bogie of the motor coach. The train can be driven from either end and coupled to another, and run as multiple units with only one man in charge. The train has given general satisfaction in the Blackpool area.

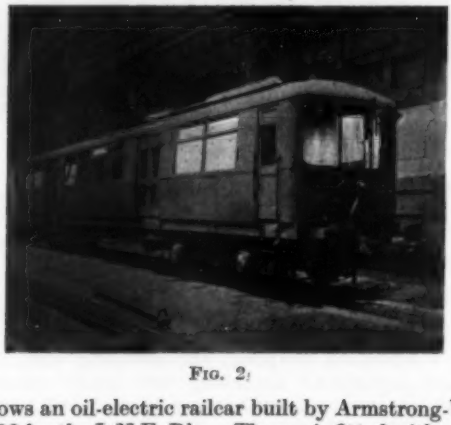


FIG. 2.

FIG. 2 shows an oil-electric railcar built by Armstrong-Whitworth & Co. in 1932 for the L.N.E. Rly. The car is fitted with a 250-b.h.p. Armstrong-Sulzer 6-cylinder engine, working at a maximum of

775 r.p.m., direct coupled to a variable voltage D.C. generator. Electro-pneumatic remote control enables the car to be operated from either end or in multiple units with trailers or other oil-electric cars.

The car has been in service 17 hours daily in the Newcastle area, though its actual running time was eight hours, but out of these eight hours the engine has been in operation only four, as during the remaining four the car has coasted down gradients, cutting down fuel consumption and wear and tear. The car holds 60 people and can haul a trailer with seats for another 90. The maximum speed is 65 m.p.h.

FIG. 3.

FIG. 3 shows the complete engine and generator being lowered into the engine compartment of the railcar.

FIG. 4 illustrates a 6-coupled 40-ton oil-electric shunting locomotive equipped with the same 250-b.h.p. engine unit as in the railcar just described.

A very interesting paper was recently read at the Institution of Mechanical Engineers (13/1/33) on the applicability of C.I. engines to railways. The author says that it is notable that, in examining the various running costs of C.I. locomotives and steam engines, the all-important items of interest on capital and depreciation are frequently omitted. The cost of a complete oil-electric locomotive is and must continue to be, eventually more expensive than the

steam locomotive. Moreover, unlike the steam locomotive, the price per b.h.p. of the oil-electric locomotive tends to increase instead of diminish with increasing size.

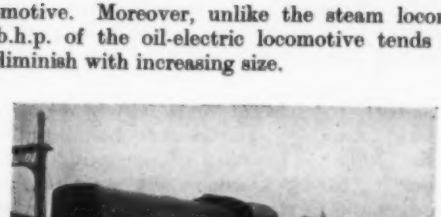


FIG. 4.

TABLE I.

Relative First Cost of Typical British Steam Locomotives.

Duty.	Type.	Weight empty. tons.	Max. b.h.p. required.	First cost. £	First cost per ton. £	First cost per b.h.p. £
Main-line Passenger (engine and tender)	4-6-0 or 4-6-2	110	2000	9000	81·8	4·5
Express Goods (engine and tender)	2-6-0	92	1500	7500	81·5	5·0
Mineral (engine and tender)	2-8-0	92	1000	6500	70·6	6·5
Branch Passenger (engine and tender)	4-4-0	85	500	6000	70·5	12·0
Standard Goods (engine and tender)	0-6-0	75	500	5500	73·3	11·0
Suburban (tank engine)	0-6-2	50	500	4750	95·0	9·5
Shunting or Light Passenger (tank engine)	0-6-0 or 0-4-4	37	250	3500	94·6	14·0

	Cost per b.h.p. £
Oil-Engine Unit	2·5
Electric Equipment (Generator with exciter; Traction motors; Control gear; Battery; Brake compressor with motor; Cabling; Erection)	8·0
Installation (Cooling; Exhaust system and carriage heating; Tanks; Framing; Wheels and axles; Brake gear)	3·0
	£13·5

Table I. is an attempt to show approximately the relation between first cost and b.h.p. required of typical British steam locomotives for various duties, and of oil-electric locomotives. Special attention is drawn to the very low cost per b.h.p. of the high-power steam locomotive. Based on the above figures, the first cost of a main-line express, passenger and express goods steam locomotives are £9000 and £7500, as compared with similar oil-electric locomotives, which work out at £27,000 and £20,250. An addition to the first cost of locomotives for main line express passenger and goods services of about £18,000 and £13,000 respectively is quite out of the question. In the case of the former, it appears that if the fuel cost of the oil-electric locomotive it displaced were nil, the increased annual charges for interest and depreciation would more than offset the total annual coal bill of the steam locomotive it displaced. It is suggested, therefore, that no case can be made for the use in this country of the oil-electric locomotive for heavy express work. For such duties there is still no serious rival to the steam locomotive.

As a substitute for electrification of suburban lines requiring a heavy service with high morning and evening peak loads, the oil-electric system does not appear very attractive. High acceleration for such services is essential. This means the provision of an engine of high maximum power with relation to train weight. As much as 10 b.h.p./ton is employed on suburban electric trains. To provide such power in an oil-electric train very clearly means very high first cost. Moreover, it would be necessary during rush hours to couple two or more generating sets into one train. The majority of these expensive generating sets must spend the greater part of the day idle in the carriage sidings while the service is being maintained with three-car trains carrying a single engine. Load factors would therefore be uneconomically low. Maintenance charges would clearly be greater for the oil-electric than for the dependent electric train. It would be necessary to allow for a higher cost of depreciation of the oil-electric generating sets than for dependent electric tracks and substation equipment. The oil-electric generating set, together with its accessories, weighs about 100 lb. per b.h.p. ; that is to say, the power plant delivers to the traction motors about 20 b.h.p. for each ton of its weight.

It will be seen, therefore, that in a suburban service calling for traction equipment at the rate of 10 b.h.p. per ton of total train load one half of the power supplied by the generating sets would be absorbed in their own transportation. This fact would seem to preclude any possibility of showing an advantage in reduced fuel costs in favour of oil-electric traction at such a power weight ratio.

It appears that for all-round economical working a ratio of 4 b.h.p./ton should not be exceeded on oil-electric passenger trains.

Duties which can be economically performed by oil-electric engines.—(1) The advantages of the oil-electric mineral engine which only needs about 1000 b.h.p. go far towards balancing the disadvantage that its first cost is about double that of the steam locomotive for the same duty. Also, it would be a great convenience to the traffic control department, and in colliery yards, to have an engine which could be worked all day without a break to clean fires or take water, and in charge of only one man, as all oil-electric locomotives and railcars can be fitted with the "Dead Man's Handle."

(2) For local passenger traffic on lines where the normal train load does not exceed four coaches, about 150 tons, and a speed on the level of 60 m.p.h. can be taken as a maximum, the balance of advantage appears to be heavily in favour of oil-electric traction, using a four-coach unit with the generators and motors in one of the coaches. While the first cost is but little increased, the full advantages detailed above would be obtainable. There would be no locomotive to change ends at the end of the journey, and the train could be scheduled to wait only a few minutes at the terminus.

(3) A general goods locomotive would also be an economic proposition, as it could use the same 500 b.h.p. oil-engine generating set as the four-coach passenger train set, thus allowing of smaller production costs and fewer spare parts.

(4) For sparsely inhabited branch lines the 250 b.h.p. railcar, capable of hauling a trailer when necessary, would be a very efficient unit.

(5) For shunting duties, the same 250 b.h.p. oil-electric set, as used in the railcar, could be employed, helping standardization, or else using hydraulic transmission with its smaller energy losses.

(6) Mobile power houses, locomotives capable of generating, say, 2000 b.h.p., but with traction motors only just powerful enough to propel the locomotive. The large excess of electrical power is passed on to the motors of an ordinary electric train, so that through trains can be run from ordinary electrified tracks on to non-electrified tracks. Here the assistance to traffic operation might justify the large capital cost of such powerful machines.

On all these services the introduction of the oil-electric system will result in a reduction in the number of locomotives necessary to operate them. While this is valuable, it must not be forgotten that the increased mileage per locomotive per annum would result in a higher rate of depreciation.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.
RUMANIAN BRANCH.

SIXTH ANNUAL DINNER.

The Sixth Annual Dinner of the Rumanian Branch of the Institution of Petroleum Technologists was held at the National Liberal Club, Ploesti, on Friday, February 3rd, 1933. Mr. J. L. Chaillet, Chairman of the Local Committee, took the Chair, and forty-three Members and Guests were present.

"The Petroleum Industry of Rumania."

Mr. J. L. Chaillet, in proposing the toast of "The Petroleum Industry of Rumania," said :

It has been our tradition that the toast of the Petroleum Industry of Rumania should be proposed by one of the non-members of our branch, who, by his office and leading position in the industry, could give those present at the Annual Dinner his views on the subject that lies so near our hearts. Regrettable absences and disappointments have been the cause of our deviating this evening from this tradition, and so I feel myself honoured in undertaking this task.

As a whole, the industry and its dependents have been suffering from the low prices of crude and products, and in this country still more, from the exorbitant taxes and charges imposed on it by the State and Municipalities.

It is at the moment certain that Rumania has still plenty of oil reserves. The development of West Gura Ocnitei was an accomplishment that showed a real boom in drilling and consequently production. This was quick and cheaply objectionable oil which was thrown on the market at a very critical moment when the world's oil industry could not stand a further disequilibrium. The assiduous attempts then of the leaders of the industry and the sympathetic attitude of the Ministry of Industry and Commerce at last succeeded in reducing the country's production to a figure of 1850 cars of crude or about 20 per cent. below its potential. Even this figure is not what it ought to be to cure the situation, and yet there is the opposition of one Rumanian company and a few small independent operators who will not see sound reasoning. But for the moment there is restriction, and let us hope that the industry will show patience and confidence for a long while. A sick man, who has been so seriously ill for a long time, cannot be cured by magic in a moment. His whole system has to undergo a process of recuperation, which needs time and rest.

In the year 1932 still more production was obtained than in the previous record year. The figures which I am able to produce are not official, but are sufficiently accurate for the purpose of demonstration.

Rumania produced in 1932, 7,336,664 tons, compared with 6,657,803 tons in 1931 and 5,744,000 tons in 1930. In other words, the 1932 production increased by 10·2 per cent. compared with 1931 and 27·7 per cent. when compared with 1930.

The total world production decreased steadily since 1930, and was 183,090,336 tons in 1932. Rumania represents thereof 4 per cent. in 1932 as against only 2·95 per cent. in 1930.

As a consequence the importance of the Rumanian crude-oil production in the world oil market has been a growing menace for the rest of the exporting oil world.

North America's production decreased by 7 per cent. during 1932, South America attained a slightly decreased total, Asia and Oceania as well as Africa remained unchanged, but Europe spoiled the world market, and its own market especially, by producing 6 per cent. more as compared with 1931 and 28 per cent. more than 1930. Europe produced in 1930 a little over 25 million tons or almost 13 per cent. of the world production, but in 1932 it produced over 32 million tons, which represents 17 per cent. of the world production. Expressed in a percentage of world production the European oil production was during 1932 in quantity 31 per cent. higher than in 1930, and Rumania had its share by being, as said before, 27·7 per cent. higher.

The Refineries increased their capacity to around 9,500,000 tons per year, against 8·4 million tons the previous year. The crude oil treated did not increase as much, namely, from 6,576,879 tons in 1931 to 7,010,216 tons in 1932 or 6·5 per cent.

The cracking capacity increased to 833,600 tons or an increase of 8·5 per cent.

The low fuel prices and the high taxes caused some refineries to burn their fuel oil in quantities with fantastic flames on the outskirts of the oil-town of Ploesti.

The desbenzination of gases increased considerably. I believe that Mr. Edeleanu, with whose name I couple this toast, will be pleased to hear that the 90 thousand tons of casing-head gasoline in 1930 were almost doubled in 1932, since it amounted to 170,000 tons. Unfortunately I could not obtain in time a figure for the total gasoline obtained in Rumania during 1932, but I am sure that desbenzination now plays in Rumania a bigger rôle in the benzine market than cracking.

The shipping and export business increased by 18 per cent. roughly. Constanta harbour showed an activity hitherto unknown.

The capital invested in the Rumanian Petroleum Industry represents about 13 million gold Lei or more than 500 million English Gold Pounds. The year 1931 showed net losses and so will 1932 on an average. The shareholders had reason to complain, because dividends were not forthcoming and share quotations were lower on an average. But how can an industry be flourishing if no sound price can be asked, or paid, for its products, and when the total taxes in percentage of the f.o.b. prices of the Export Station amount to 29·7 per cent. ? The inland market is worse still. In 1931 there was a burden of taxes of 72·7 per cent. of the total sales value.

Let us be glad and proud that the industry itself is trying to find a way out of the darkness by studying international co-operation which oversteps National boundaries and overcomes the difficulties arising from exaggerated local and national competition.

The oil is there, the skill is more developed, the studies are more advanced, and Rumania's petroleum industry came up to the international standard of efficiency. But we need a cool head and self-control to overcome all sorts of crises, amongst which the lack of confidence seems to be a moral crisis.

Inasmuch as patience is a necessary quality during all hardships, it is this that I wish the Rumanian Petroleum Industry in asking you to raise your glasses to its everlasting health.

The toast of the " Petroleum Industry of Rumania " was then honoured.

Mr. Ion Edeleanu, B.Sc., D.I.C., who responded to the toast, said : I am afraid that, after the toast so ably proposed by our Chairman, what I shall say will be looked upon as a very meagre contribution. If my reply will not be very documentary, it will at least be a very short one. Mr. Chaillet gave a very clear picture of the present state of the Rumanian oil industry. He based his statements on figures, and we all felt rather proud of the progress described, which we took as a sort of reflected merit upon ourselves. The importance of the Rumanian oil industry in the world oil industry must not be judged, however, merely by its share in the total world crude oil production, or by the increase from one year to the other. Its importance rests mostly on its exporting capacity. Its share in the total exports from the producing countries to the consuming markets practically doubled from one year to the other. Mr. Chaillet made a very true remark, namely, that we are suffering from a moral crisis—lack of confidence. Oil technique demands continuous progress, and it would be an irreparable loss if lack of confidence should handicap progress. Healthy optimism should be the characteristic of our industry, and such optimism is justified by the consideration that we have

survived a drop of prices beyond all expectations and a rise of taxation beyond imagination. With full confidence in the vitality of the Rumanian oil industry I raise my glass in response to the very able speech of our Chairman.

"The Visitors."

Mr. C. M. Leitch, in proposing the toast of "The Visitors," said: Mr. Chairman and Gentlemen, on behalf of the Rumanian Branch of the Institution of Petroleum Technologists, I have been asked to propose the toast of our Visitors to-night. A few weeks ago some of us had fear that the Annual Dinner might fall flat, and when it was suggested that this honour to-night should be conferred on me, our esteemed Secretary led me to understand that there might be two or three distinguished guests present. But when I look round the table and see so many leaders of the industry, I feel that I am not fit to bear the honour of welcoming them.

However, it is a pleasure to me to propose their health and a joy to see so many different nationalities represented to-night, which bears out what I have thought for a long time, namely, that Rumania extends its hospitality to all technologists, indifferent of nationality.

I have much pleasure in welcoming Mr. Krupensky to-night, who occupies a high position in the Mining Department of the State, and I hope he will favour us with his presence on many future occasions.

At the last dinner of the Institution of Petroleum Technologists in London, one of the speakers had the happy idea of making special mention in his toast of the supplier, and it is my pleasant duty to follow suit in welcoming the members of the supply fraternity to-night.

It is scarcely necessary for me to remind you of the enormous debt (I mean moral debt, not financial debt) we owe to the supply houses which have kept abreast of the requirements of the petroleum technologists, both in the fields and in the refinery, and at times the foresight of the supply man has even anticipated our needs. To-night I extend a hearty welcome to all equipment suppliers, and I ask you, gentlemen, to drink to the health of our distinguished guests, coupling with the toast the names of Mr. Krupensky and Mr. Hunter.

Mr. Krupensky, the Regional Director of the State Mining Bureau, then replied to the toast on behalf of the Visitors.

Mr. F. E. Hunter, in replying on behalf of the supply fraternity to Mr. Leitch's toast, said :

Virtue, a quality for which supply men are notorious, is its own reward. Nevertheless it is gratifying, even at this late date,

that there should be accorded to suppliers a modest meed of deserved praise such as was referred to by Mr. Leitch.

From such recognition of their services, which are said to have contributed in no small measure to the present depressed situation, suppliers must find such solace as they can in the lean years through which we are all now passing.

On behalf of the local supply fraternity I heartily thank you for your cordial reception on this and on many other occasions, and for the genial hospitality which is always extended to us by the Rumanian Branch of the Institution of Petroleum Technologists.

"The Rumanian Branch of the Institution of Petroleum Technologists."

Mr. A. H. Chapman, in proposing the toast of "The Rumanian Branch of the Institution of Petroleum Technologists", said: I want to thank the Committee for affording me the opportunity of proposing this toast. It is always a pleasure for me to attend the meetings of this branch. I have always noted a splendid spirit of tolerance and goodwill between the members and their friends. Large doses of this very spirit injected into our business to-day will act as a powerful antidote to our present evils. To-day's proration is a step in the right direction; but its purpose will be defeated if adherence to the agreement is not tempered with goodwill. This Institution, through its Rumanian Branch, is one of the country's most powerful instruments in maintaining this spirit. Therefore, it is with great pleasure that I propose the toast of "The Rumanian Branch of the Institution of Petroleum Technologists," coupling with it the name of Mr. F. W. Penny, the Hon. Secretary.

Mr. F. W. Penny, in replying to the toast, said: I should like to first of all thank Mr. Chapman for the words of appreciation that he expressed about our organisation; and, secondly, to thank you, gentlemen, for the cordial way in which you received the toast.

I think that the fact that this is our Sixth Annual Dinner, and that there are some fifty of us here to-night, is evidence that the idea of our Parent Institution in starting and financing this Rumanian Branch has justified itself. When Dr. Dunstan came out here in 1926 to inquire about the starting of an official branch —for we had an unofficial one before he came—he told us that he looked to us as a means of swelling the bulk of the Journal. I may mention that during our existence we have held 38 General Meetings and have submitted to London 20 Papers for publication. Of these, 10 were published in full, 5 in abstract and 5 were not

published. In view of Mr. Chapman's remarks about the opportunity afforded to non-members of taking part in our meetings, it is interesting to note that 5 of these 20 Papers were contributed by non-members of the Institution.

As may be guessed from these statistics, the attitude of the Publication Committee has varied somewhat from time to time. After a pretty good start, our contributions did not appear to come up to the standard required of the Journal, and more recently there has been an unconscionable delay between their arrival in London and their appearance in print. When I was in London last September, I mentioned this to the Associate-Editor, and found that the reason was that he had a plethora of material for publication, and that our contributions had to wait their turn. However, things may be better in the future, because we have recently received a letter from London stating that the Publication Committee have decided that space shall be devoted in the Journals to reports of meetings held by our branch.

But the function of this branch is not only to give the members a chance of seeing their Papers in print: we hope to carry on without that incentive, however disappointing to us the actions of the Publication Committee may be. We foregather for helpful discussions and to meet our colleagues.

The attitude of the Council in London has been invariably helpful: they have generally fallen in with any suggestions that we have made to them, and we have never had any anxiety with regard to finance—a very important matter. I may mention that up to now this branch has cost the Parent Institution £169 spread over 6½ years.

Recently the Council gave us a very handsome present, a complete set of the Journals from the commencement, and I am glad to be able to announce that they have arrived in good order and are now through the Customs. We are having a small bookcase made to hold them, and they will be housed for any of us to refer to or borrow in Capt. Treacy's office, by his kind permission.

The branch has received another gift recently—a large engraving containing the portraits of many members of the Institution. It has been presented to us by our friend Mr. Edeleanu, and we have had it framed. It seems to have been made about six years ago, and it is interesting to have photographs of many of the prominent members of the Institution. But I have looked in vain for any of our members out here, so probably it was confined to those members resident in England at the time.

Mr. Chapman mentioned the Committee: that gives me a chance of saying that you have a Committee who do not believe that a period of depression is the time for a period of inactivity,

and who do what they can to make the branch progress and prosper. I say "what they can," because without the assistance of the members they can do very little. The life of the branch depends upon members and their friends coming forward with interesting Papers, and encouraging the authors of Papers by turning up in good numbers to hear and discuss them. They need not be elaborate theses: in fact, the Editor of the Journal wrote to us recently and suggested that Notes regarding matters of interest in the Petroleum Industry which might take place in our part of the world could be regularly sent to him for publication in the Journal.

One effect of the alteration that we made in our Constitution last year is that a new member is required to be elected to the Committee at every Annual General Meeting to take the place of the member who has acted as Chairman for the year and who becomes an ex-officio member of the Committee. This makes the Committee more democratic, and we hope that you will avail yourselves of this change by sending in nominations for the Committee at the Annual General Meetings: they have not been very frequent of late years.

In conclusion, in again thanking this large company for the cordial reception they have given this Toast, I may express the hope that it is a sign of continuing interest in our branch, and that with the help of everybody—not only the Committee—we shall carry on for many years more, and so justify the trust which was placed in us by our Parent Institution 6½ years ago.

Mr. W. Bolton then proposed a Vote of Thanks to Mr. Chaillet for his occupancy of the Chair, which was accorded with musical honours; and **Mr. T. P. Perrott** proposed a Vote of Thanks to Mr. P. R. Clark for the part he had taken in the organisation of this very successful dinner.

CORRESPONDENCE.

June 15th, 1933.

To THE EDITOR.

SIR,—May I point out in reply to your correspondent, Mr. T. R. H. Garrett, that date of publication is still the acid test of priority. The points at issue between Dr. Murray Stuart and Mr. Munn were very definite indeed ; however, they were not primarily concerned with the subject of oil migration but rather with the physics of oil sedimentation. Mr. Munn's publication was the earlier of the two, and within the limits of the subject which I was considering. I had no option but to give the credit to the earlier author.—Yours faithfully, V. C. ILLING.

"Bituminous Emulsions for Use in Road Works."

By WILKINSON and FORTY.

May 20th, 1933.

To THE EDITOR.

SIR,—We are naturally pleased to be accorded such generous space in your journal for a review of our work, notwithstanding our avowal of the limitations of our book and the definite disclaimer of its having any pretensions to be a work for chemists or petroleum technologists.

The importance and wide circulation of your journal, however, might make the damaging effect of adverse criticism in it very considerable, and in view of the constant recurrence in the review of the word " inaccuracy " as applied to our work we are impelled to draw your attention to certain points.

Passing by the first criticisms, which although perhaps unnecessary in view of our disclaimer, are by their suppositious nature harmless enough, we come to this remarkable statement :

> " It is regrettable to find the authors falling into the very common error of treating the bitumen phase of a normal bituminous emulsion as colloidally dispersed."

Needless to say, the authors do nothing of the sort, and we can only regretfully feel that if your reviewer had not been so anxious to show that parts of our book were *written* inaccurately he would not have *read* it inaccurately and could not possibly have made such a statement, which apart from the general context throughout

the book is, of course, quite irreconcilable with our words on p. 45, when, referring to bituminous emulsions, we say :—

" If the sub-division of the binder is colloidal, then the dispersions are technically *suspensoids* or *emulsoids* according to type." (The meaning of the terms suspension and emulsion colloids—suspensoids and emulsoids—having previously been explained.)

Supposing that your reviewer unfortunately missed this page, then the substance of his next point of criticism—viz., in regard to particle size, where we refer to certain *normal* emulsions which are obviously *well* outside the colloid field, would form a direct contradiction and should have been sufficient to remove doubt from his mind.

Referring in detail to this particular criticism, for your reviewer to term as erroneous our statement regarding the average particle size of emulsion prepared in a certain emulsifying machine (10–15 microns), and for him to say that emulsion containing any great percentage of particles of diameter 10 microns would be unsaleable, is not altogether without its amusing side, having regard to the fact that the size was originally determined, and the figure supplied, by the producers of the emulsion, and confirmed, and that (though the particle size was then admittedly a large one), as far as saleability is concerned, we ourselves have bought and used many thousands of gallons of it in connection with the successful carrying out of very many thousands of square yards of road works.

Your reviewer is no doubt familiar with, though perhaps he has momentarily overlooked (even Homer being not unknown to nod), the particle sizes of some of the earlier emulsions prepared some years ago, when the degree of dispersion was considerably less than at the present day in emulsions prepared in modern homogenizers and by modern processes. Though even to-day the figure of 1·0 or 1·5 which he quotes is probably an unusually fine one, and it would be interesting to know how many manufacturers normally achieve this degree of dispersion in the greater part of their emulsions. More probably the average is two or three times as great as the dimensions he quotes.

As far as " attempting too much " is concerned, we believe there is no question, even by your reviewer, that a gap existed in the literature on the subject available to the road engineer; that gap we attempted to fill, and apparently, according to expressed credible opinion from many parts of the world, we have succeeded, although the collection of the requisite information was at times difficult.

It is not our practice in the ordinary course to reply to reviews in journals, but having regard to the highly important position occupied by your Institution and the circulation of its valuable journal, we feel such reply to be desirable and apologise to you for its necessary length.—Yours faithfully, F. WILKINSON.

F. J. FORTY.

June 7th, 1933.

To THE EDITOR.

SIR,—I am at the moment without access either to the book or to my review. I can, however, make the following points :—

1. As regards the question of the colloidal state of the binder in emulsions, I refrained from referring to the apparent contradiction between the statement to which I referred and that put forward by the authors, because I did not wish to be unduly severe.

2. I am afraid I cannot quite understand what point the authors wish to make in connection with average particle sizes. It would be as well to be clear, however, that *all* normal emulsions are outside the colloid field if reference is made to the dispersion of the binder. In its present wording the criticism shows clearly enough that the doubt existed in the authors' minds, whatever the reviewer felt.

3. The authors do me less than justice in their allusion to emulsions with average particle sizes from 10–15μ. I say quite categorically that there are no such emulsions on the market, for normal road building purposes, and to my knowledge there never have been. I am glad, however, to see that the error in determination is not to be attributed to the authors, but to someone else. I suggested 1·0–1·5μ as what the authors intended to have printed, but for a typographical error, and had they done so I should not have quibbled, although I agree with them that from two to three times these figures might be more generally applicable. A lot depends, of course, on how the figures are determined ; the maximum of the size frequency curve normally comes somewhere near 2μ.

The reviewer quite well remembers the early emulsions, *and* their lack of stability, which would render them quite unsaleable to-day.—Yours faithfully, (Signed) LEONARD G. GABRIEL.